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SÁNDOR KOCH

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Kiadványunk címének rövidítése
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DATA ON THE GEOLOGY AND MINERALOGY OF THE MANGANESE ORE DEPOSIT OF URKUT. I.

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Manganese Ore Mines of Urkut

INTRODUCTION

The manganese ore occurrence of Urkut is one of the most important ones of Central-Europe, hence, it is comprehensible that several workers dealt with it from geological and mineralogical viewpoint. References are referred to only in enumerating the most significant works.

The ever increasing requirements of the production and ore dressing, further the different industrial pretentions necessitated a more detailed and systematic examination of the occurrence. These investigations aim at the furtherance of the production as well as broadening the scientifical knowledge concerning the deposit.

The final goal of these investigations carried out by systematic geological, mineralogical and geochemical examinations is to outline the characteristic features of the differently developed ore-fields of the manganese oxide deposit of Urkut as well as to learn in details its genesis.

For this purpose seemed to be the convenient to carry out the initial investigation of the area of the „Lejtakna" (Slope) as its exploitation is at present under way, thus its characteristics can be traced. These examinations are, however, supported also by the mining points of view as this field offers one of the best quality ores.

The manganese oxide ores of upper Liassic age in Urkut was recognized in the field connected with to-day's „Lejtősakna" (Slope) in 1917 by V. MENYHARDT. The mining started in 1935 proceeded at fluctuating rate in the shaft No. I, when considering this field as being exhausted, the present Slope was deepened in 1952—53 to exploit the pillar of the shaft No. I. These works resulted in the prospection of the south-eastern region of the Slope from 1958 on.

The south-eastern area of the Slope is located on the plateau embraced wedgelike by faults of post-Eocene age which limit the Csárda Hill and Köves-tábla. The manganese oxide ore deposit is located in this field complicated by faults and folds. On the southern edge of the deposit a transitional zone between the carbonate and oxide ore types is stretched. The manganese oxide deposit situated in a basin-like structure is lobedly denudated on higher levels. The autochtonous deposit is bordered by a pisolitic, red clayey, detrital zone as shown in *Fig. 1.*

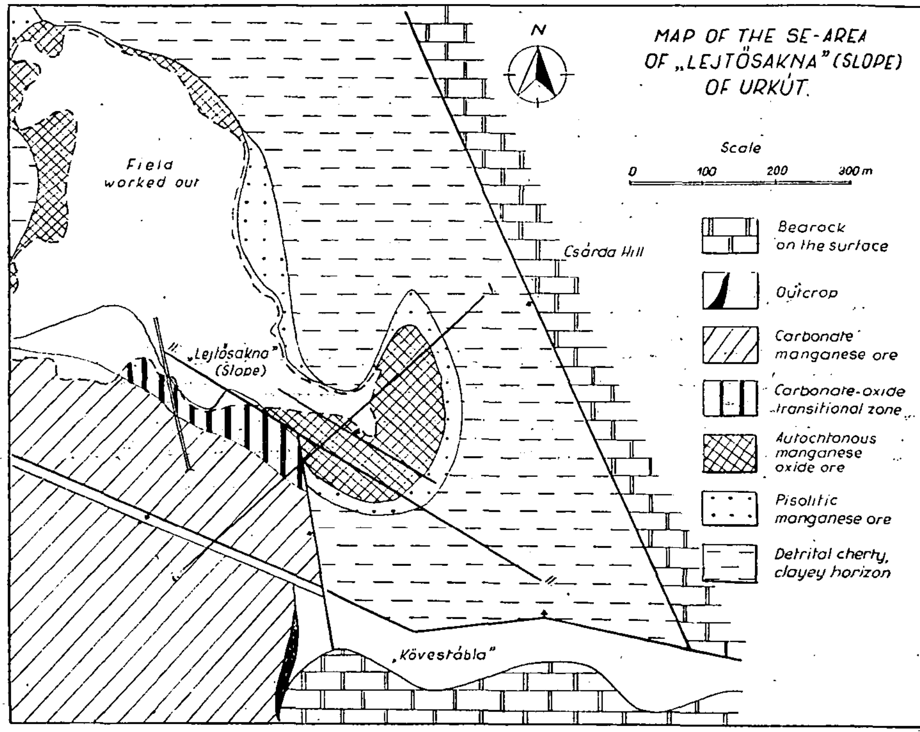

Fig. 1. Map showing the generalized surficial geology of the Slope

The south-eastern part of the Slope is of discontinuous development. On the lower-, middle- and upper-Liassic rocks upper-Cretaceous clay and thereon stretching further lower-, and middle-Eocene layers are deposited.

Lower Lias: The lower Lias is represented by rynchonellian cherty limestone. This series is connected with the field of the southern edge where also Liassic rocks are on the surface.

Middle Lias: The middle Lias is represented by red-pink cherty limestone, chert-flour, clay with detrital chert and chert-banded clay found in the immediate bedrock. The red—pink limestone reaches 35—40 m thickness, usually is of thick bedded character, whereas in general on the upper part is nodular. On the greater part of the area the more spread rock is the chert-flour which is the altered type of the cherty limestone or the chert rubble. On the eroded areas the middle Lias is represented by red, detrital-cherty clay. This rock consists of the several times re-deposited material of the cherty limestone of middle Liassic age. Of course, the ore deposit is absent over such areas. In the immediate underlayer bedrock of the autochtonous ore deposit brown, chert-banded clay of 0,1—1 m in thickness is settled.

Upper Lias: The upper Lias formation consists of carbonate and oxide manganese ores and the rocks accompanied the ores. In the ore series different rocks can be found. At the south-eastern edge of the Slope a manganese carbonate ore bed trends. The manganese carbonate ore developed here in two

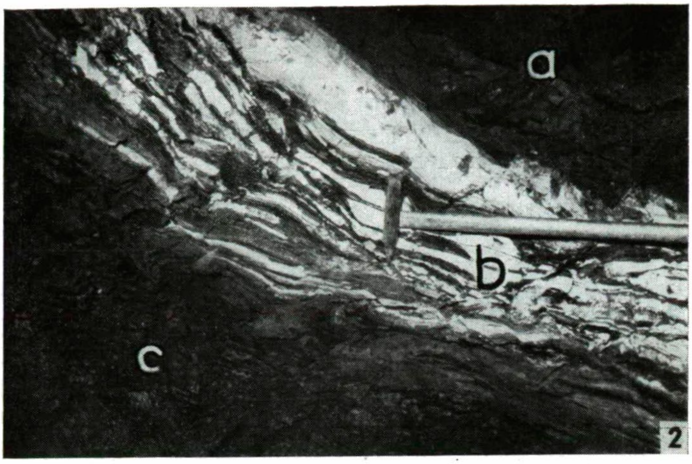

Fig. 2. a) radiolarian clayey marl; b) manganese carbonate layers; c) layered manganese oxide ore

main-types. Beneath brown — light brown, fine-striated, while above green — light green — brown, coarsely-banded manganese carbonate ore is located. At the boundary of the two types a gray, rodochrositic bed of 15—20 cm thick is generally located, containing often 30 per cent or more manganese *(Fig. 2.)*.

The ore deposit in general has a thickness of 5—5,5 m. The manganese carbonate ore is overlain by dark gray, radiolarian clayey marl bed. This rock here has turned clayey in some places bearing vestiges of alteration.

The manganese oxide ore is developed in several types like the manganese carbonate ore. Its lower part as a rule is clayey and of layered development *(Fig. 3)*, whereas its upper part is clayey but nodular *(Fig. 4)*.

The thickness of the manganese oxide ore bed is ranging from 4,5 to 5,5 m on the south-eastern part of the Slope. Towards the eroded edges manyfolded, re-deposited, detrital ore types appears in the place of the layered, nodular types of the ores. On the eroded parts at first the material of the ores is less contaminated, further on, however, firstly chert rubble, red clay appear and finally the deposit turnes barren *(Fig. 5)*.

In the roof of the manganese oxide deposit the yellow, white mottled radiolarian clay, the altered type of the dark gray radiolarian clayey marl is frequent.

Lower Cretaceous: It is represented by gray clay, limestone-detrital clay extending tongue-like into the western part of the area.

Lower Eocene: The whole area is covered by lower- and middle Eocene rocks. On the basis of the series usually red clay, bauxitic clay, light gray, pyritical clay is located. The characteristic rock of the lower Eocene is the dark gray carbonaceous clay. The middle Eocene is represented by nummulitic limestone. The series is considerably broken due to late tectonical movements and owing to its aquifer character is dangerous for mining.

Pleistocene: The whole area is covered with pleistocene clay, yellow, sandy loess ranging in thickness from 5 to 10 m.

The sections I–I and II–II, respectively, of the field of the Slope are shown in *Fig. 6.*

Fig. 3. Loose, layered manganese oxide ore.

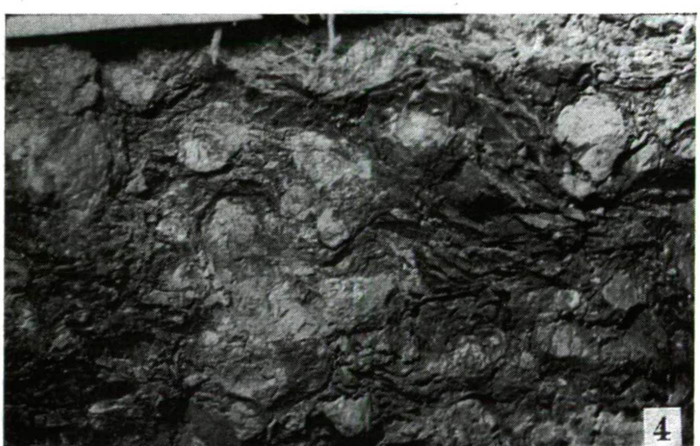

Fig. 4. Nodular manganese oxide ore

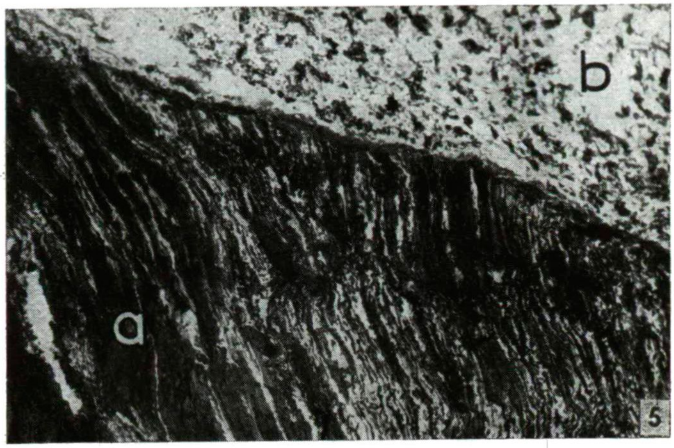

Fig. 5. a) layered manganese oxide ore; b) pisolitic ore

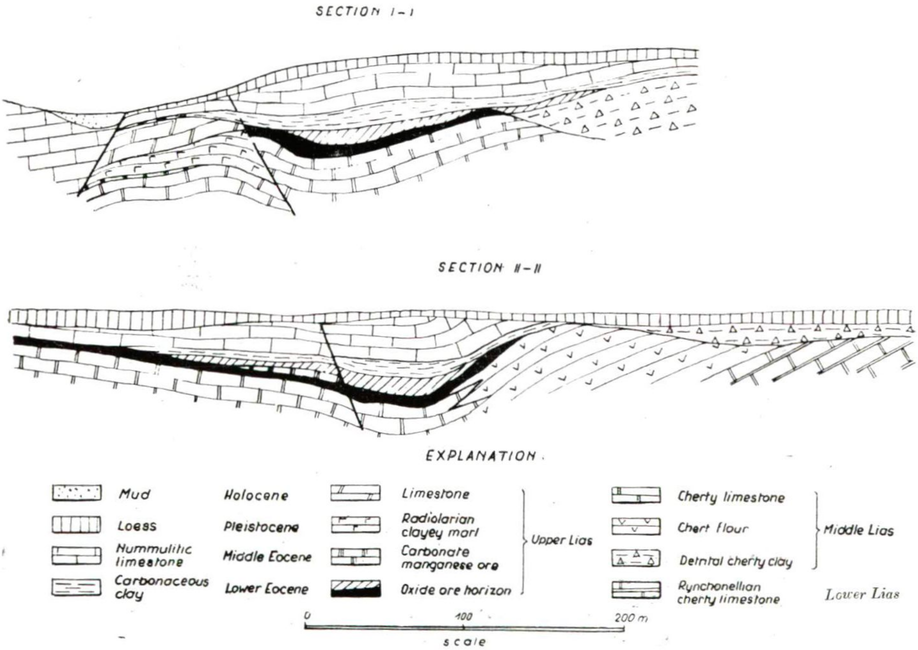

Fig. 6. Section along I—I and II—II.

The structure and composition of the manganese oxide deposit of the Slope

The real value of the area prospected is the manganese oxide ore deposit of high quality whose thickness ranges from 4,5—5,5 m on the basis of the data obtained. The structure of the deposit in general shows no considerable variations. The best illustration of the sequence of the strata is shown in *Fig. 27.*

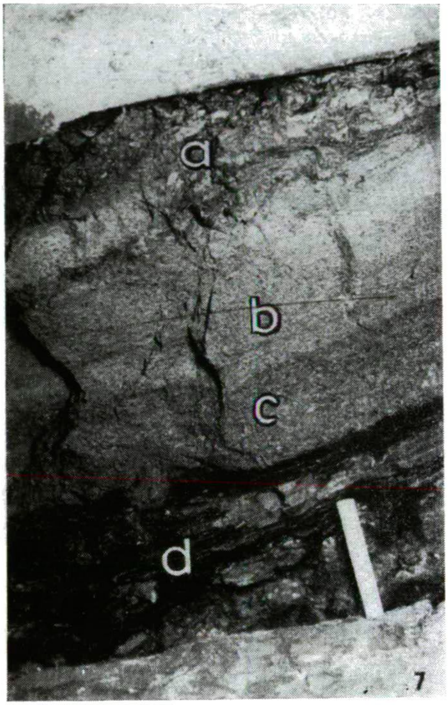

Fig. 7. a) nodular oxide ore; b) yellow ferruginous layer („iron-sand"); c) fine-grained, loose „manganese-sand" layer; d) black, layered, clayey manganese ore

The ore series is immediately underlain by brown, chert striated clay *(m)*. At the basis of the ore series a brown clay of 30—60 cm thickness is located often containing also manganese granules *(l)*. Thereupon there is superimposed a loose, black manganese oxide ore *(k)* frequently containing ore nodules of 1—5 cm in size. The material of these nodules is mainly cryptomelane. The ore contains then and there 38—40 per cent manganese, however, 30 per cent is ever reached, even sometimes surpassing it. The thickness of this layer is 1,50—2.0 m. On this stratum a bluish gray, fine-grained „manganese-sand" is deposited in a thickness of 10—50 cm *(j)*, drawing the attention with its striking bluish-gray color, loose structure and with extremely high — 48—50 per cent — manganese content.

Close on the „manganese-sand" a yellow, ferruginous layer *(i)* of similar structure with a thickness of 5—10 cm follows. The iron content of this layer is 45—50 per cent, whereas its manganese content is very low, nearly 1—2 per cent. The iron is present in this layer as limonite as it is shown by DTA examination. Over these fine-grained strata a compact bed *(g)* is often located in a thickness of 10—20 cm. The bulk of its material is dense, cryptocrystalline cryptomelane with pyrolusite. In the section studied a thin white-yellow clayey layer *(h)* is discernible, this, however, appears not generally.

On the above-mentioned layers a brown — light brown fine striated clay bed *(e)* of 2—2,5 m thickness is deposited, wherein ore nodules of 5—20 cm in size are embedded. The matrix of the ore nodules largely consists of cryptomelane, wherein pyrolusite veinlets can often be observed. The iron content of the clay is often over 20 per cent; the manganese content of the nodules is 40—45 per cent. In some places between the strata *e* and *g* — as seen also in the section in Fig. 27. — a brown, clayey, layered manganese oxide ore bed is found *(f)*.

In the upper part of the deposit another 0,5—1,0 m thick brown, striated, clayey, layered manganese ore bed is located *(d)*, whereon often pyritic, manganese carbonate containing, green clayey layers *(b)*, followed by dark gray, radiolarian clayey marl *(a)* and as alteration product of the latter, yellow clay *(a1)* is deposited. In the upper part of the deposit over or betwixt the green clayey carbonate strata a manganese ore layer *(c)* is located of some cm-s thick as seen in the section.

MANGANESE OXIDE MINERALS OF THE ORES

On the basis of microscopical examination the presence of the cryptomelane, pyrolusite and manganite among the different manganese oxide minerals can be undoubtedly established in the ores of the Slope.

The cryptomelane is fairly abundant in the ores. The bulk of the ores is often built up from it. The cryptomelane is commonly cryptocrystalline, forms very fine-threaded, feltlike aggregates. The cryptomelane — depending upon the grain-size, the porosity — sometimes can be well polished, sometimes is too porous and it is not or poorly polishable. The botryoidal, concentrical globular structure, colloform banding, rhythmical layering characteristic of crystallization from colloidal state can often be seen on polished ore sections as seen in *Figs. 8, 9, 10* and *12.*

Sometimes icycle-like aggregates of the very fine-threaded cryptomelane are also to be observed as seen in *Fig. 10.* The aggregates are almost normal to the surface of the botryoidal, globular structure. The cryptomelane is often replaced by pyrolusite. The replacing extends either from the edges of the cryptomelane veinlet towards its center as seen in *Fig. 11,* or along fine fissures tends from the center outwards. The massive replacement intergrowth of cryptomelane and pyrolusite as well as the symmetrical layering made up alternately by thinner or thicker cryptomelane and pyrolusite layers can also be found.

The pyrolusite is also very abundant in the manganese ores of the Slope. Its appearence is fairly manyfold. It appears in fine crystalline form interwoven the similarly fine crystalline matrix made up mainly from cryptomelane. The cryptomelane-replacing pyrolusite is often very fine grained. Occurs, however,

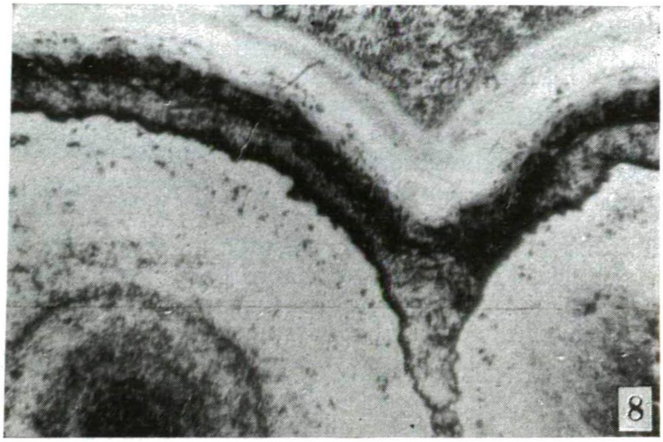

Fig. 8. Concentrical globular structure of cryptomelane. The center of the globules is too porous to polish. The cavity between the globules and the shell filled out by manganite. Plain light, ×25.

Fig. 9. A detail of a concentrical, botryoidal structure. At left cryptomelane (gray) followed by a pyrolusite layer (white) the center of which is porous. The pyrolusite layer is limited by a very thin sammetblende (Nadeleisenerz) veinlet from the manganite (right, medium gray). A manganite veinlet cuts across the cryptomelane and pyrolusite in southeast-northwest direction. Plain light, ×100.

Fig. 10. An other field of the same surface as shown in Fig. 9. but photographed with crossed nicols. At left fine-threaded cryptomelane aggregates nearly normal to the surface. At the top a thin manganite veinlet — the same as in Fig. 9. — trends in west—east direction. Crossed nicols, ×50.

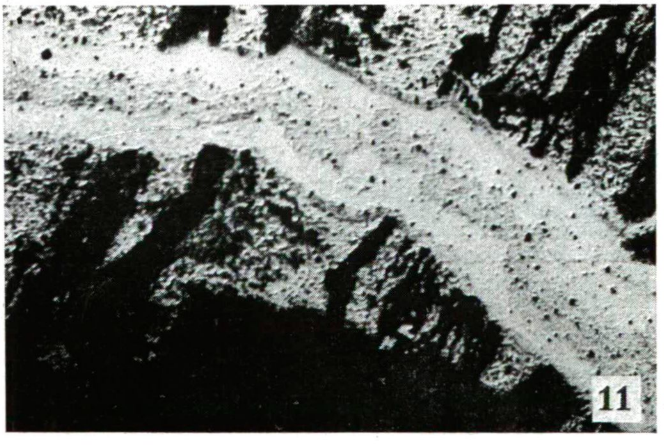

Fig. 11. Cryptomelane veinlet (medium gray) replaced by pyrolusite (white) progressing from the edges toward the center. Plain light, ×50.

in form of fine-grained aggregates appearing in patches in the matrix. It may occur also in coarse-grained fibrous aggregates even in veins, when presumably replaced the formerly vein-filling manganite. Often can be seen that the pyrolusite entangles in thinner or thicker veinlets the porous matrix as seen in *Fig. 15*.

In the ores of Urkut also the manganite is not a rare mineral. Its well developed crystal aggregates intruding into the cavities filled out by chalcedony, can often be found as shown in *Fig. 16*. The manganite occurs frequently as

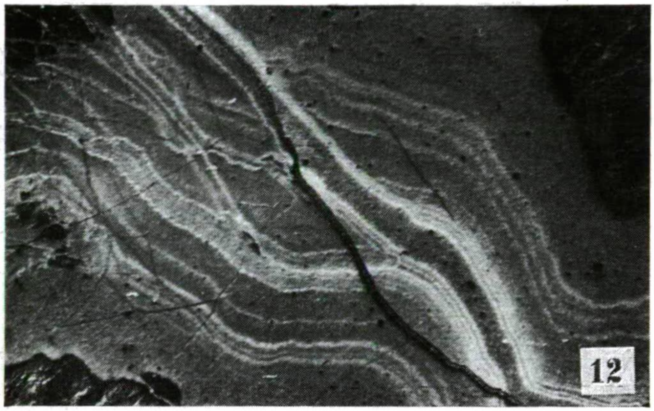

Fig. 12. A complex symmetrically layered veinlet made up from cryptomelane (gray) and pyrolusite (white). Crossed nicols, ×50.

Fig. 13. Cryptomelane (medium gray) replaced by pyrolusite (white). Crossed nicols, ×50.

cavity-filling, sometimes in coarse-grained crystal aggregates as seen in *Figs, 17* and *18*, or in veinlets filling out fine fissures as seen in *Figs. 10* and *19*. Manganite crystal aggregates can also be found in some concentrical globular structures in cavities between the shells *(Figs. 8—10.)* which cavities are presumably caused by shrinkage due to crystallization from the earlier colloidal state. Where the manganite as cavity filling occurs, it is surrounded by a thin layer of sammetblende (Nadeleisenerz). It is presumable that this layer protected the manganite from a later oxidation. It is to be noticed that the blood-red inner reflex characteristic of manganite can often be observed.

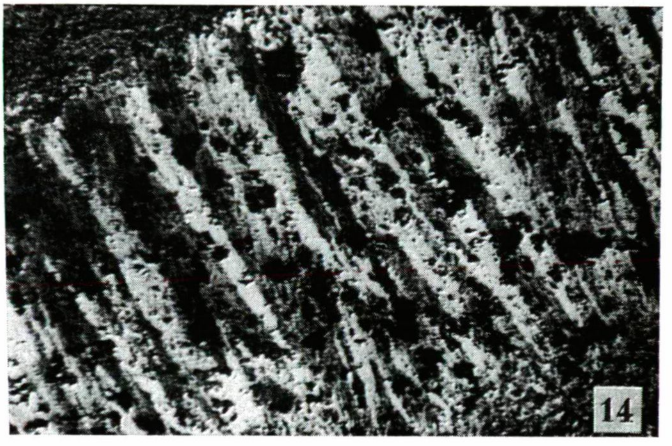

Fig. 14. Coarse fibrous crystal aggregate of pyrolusite forming veinlets of 1 mm thick in cryptomelane. Crossed nicols, ×50.

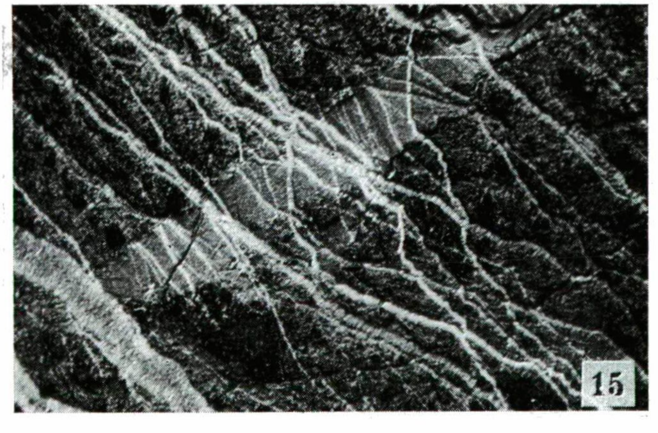

Fig. 15. Pyrolusite veinlets (white) entangle the porous matrix (dark gray). Crossed nicols, ×50.

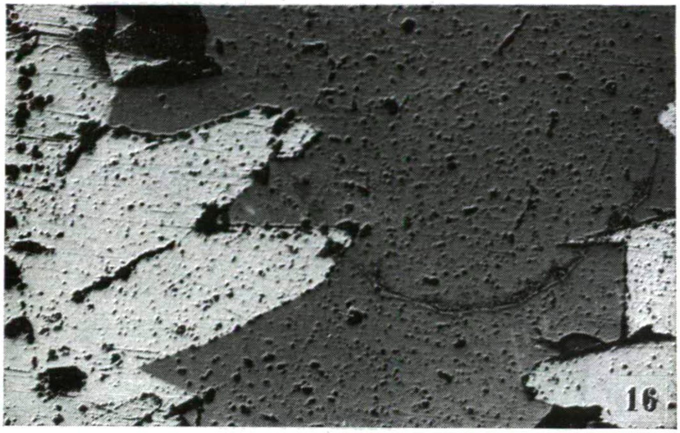

Fig. 16. Manganite crystals intruding in cavity filled out by chalcedony.
Plain light, ×100.

Fig. 17. Coarse-grained crystal aggregate of manganite bordered by fine-grained manganite of mosaic structure. Crossed nicols, ×100.

Fig. 18. Coarse-grained manganite as cavity-filling bordered by a thin layer of sammetblende (Nadeleisenerz). Matrix is cryptomelane. Crossed nicols, ×100.

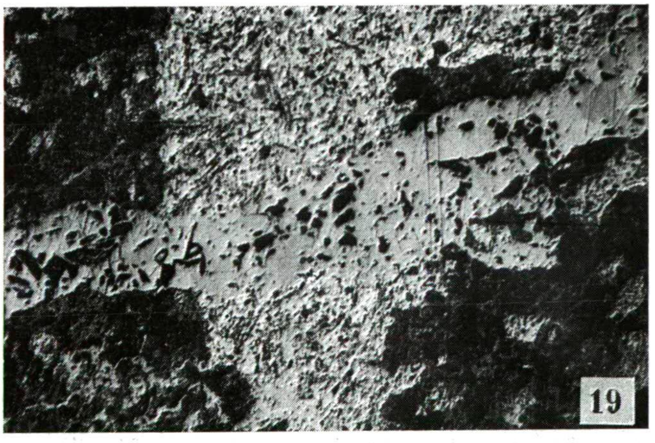

Fig. 19. Manganite veinlet (light gray) cuts pyrolusite aggregate (white). The manganite in the veinlet is fairly coarse-grained, the pyrolusite is fine-grained of mosaic structure. Plain light, ×50.

FREQUENCY DISTRIBUTION OF SOME ELEMENTS IN THE ORES OF THE SLOPE

The frequency distribution of some components has also been examined on the basis of analytical data of 230 samples collected systematically from the area of the Slope. The analyses were carried out by the Laboratory of the Manganese Mines of Urkut. The authors are indebted to Dipl. Chem. Ing. J. Szabó and his co-workers for the data. The analyses refer to the Mn, Fe, P, SiO_2 content of the samples.

The histograms showing the frequency distribution of manganese also supports the statement that the ore of the Slope is of high quality. In the histogram *(Fig. 20)* a sharp, dominating maximum can not be seen; between 26 per cent and 42 per cent manganese, however, a flattened maximum can be established, wherein the sorting shows no considerable fluctuation. Nearly 77 per cent of the samples ranges between the limits mentioned.

The frequency distribution of the iron content is quite of a different

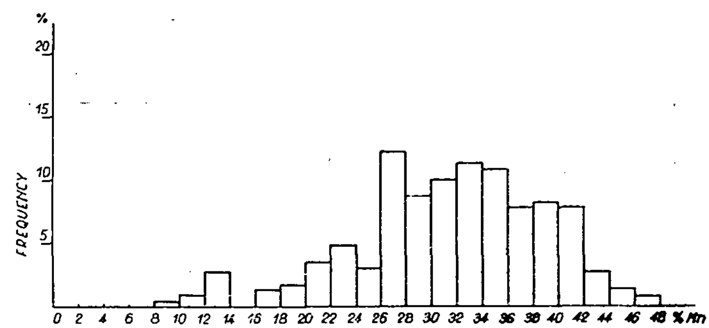

Fig. 20. Frequency distribution of the manganese.

character. The iron content varies from 2 per cent to 30 per cent, that is, between smaller limits than the manganese content. A dominating maximum appears between 10 and 12 per cent followed by a lower second maximum at 18—20 per cent and by a still lower third maximum at 26—28 per cent. The Fe content in most of the samples — that means 70 per cent of the samples — is between 6 and 14 per cent. The second and the third maxima appear presumably due to the relatively high iron content of the clayey matrix wherein nodular oxide ore is embedded. The Fe content of the ferruginous clayey material is considerably higher than that of the ore nodules embedded in it. Thus, e. g., an ore nodule separated from the clayey matrix of the stratum *c* contains 41,30 per cent manganese and 9,07 per cent iron, whereas the manganese content of the clayey material is only 0,82 and its iron content is 25,83 per cent. In an other sample from the same layer the manganese content of an ore nodule is 39,14 per cent and the iron content 9,56, whereas the nodules-embedding clay contains 30,99 per cent iron and 2,88 per cent manganese.

The histogram of the SiO_2 distribution is bimodal showing two maxima, the first appears at 6—8 per cent, the second one at 10—12 per cent. The SiO_2

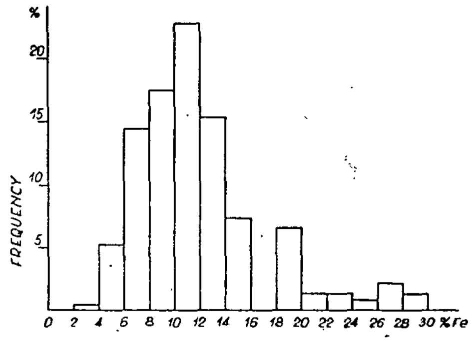

Fig. 21. Frequency distribution of the iron.

content generally changes from 2 to 26 per cent; higher SiO_2 content than the upper limit mentioned can only be established in 1,6 per cent of the samples.

The frequency distribution of the P content is of interest from practical point of view. The P content varies between 0,00—0,70 per cent; the dominating

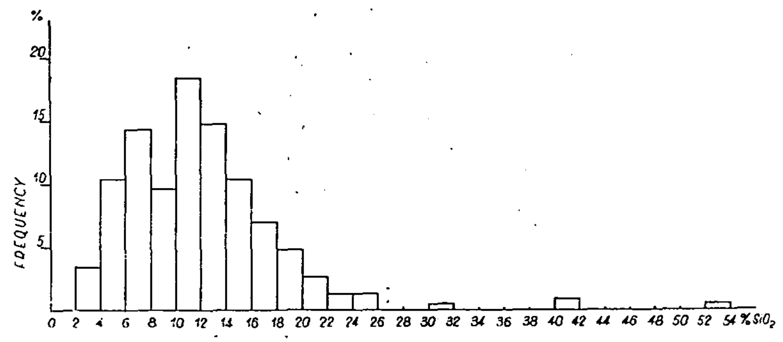

Fig. 22. Frequency distribution of the SiO_2.

maximum lies between 0,20—0,25 per cent P content. The phosphorous content of the bulk of the samples is over 0,20 per cent P which fact is to be taken into consideration at the ore dressing and using.

On the basis of these data it was also studied whether or not a relationship between the P—Fe and P—SiO_2 contents of the samples can be found.

ASOKE MOOKHERJEE [1961] dealing with the distribution of minor elements of gonditic manganese ores, states that the P content in the ores mentioned generally increases by increasing Fe content. This statement is supported by him by plotting % P *versus* % Fe of 159 samples.

The diagram plotting the % P *vs* % Fe of 230 samples collected from the area of the Slope, shows a similar relationship as mentioned by MOOKHERJEE. The two diagrams are of the same character. The relationship is interpreted by MOOKHERJEE as chemisorption of PO_4 anions on the colloidal $Fe(OH)_3$. In his opinion the lower line (denoting also in our diagram) would represent

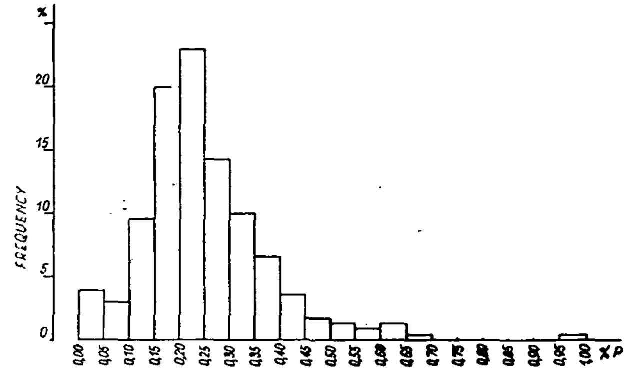

Fig. 23. Frequency distribution of the phosphorous.

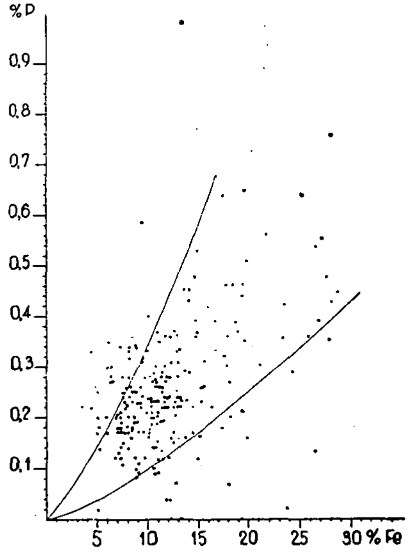

Fig. 24. Relationship between the P and Fe content of 230 samples from the Slope.

the „threshold" concentration of PO_4 anions needed to flocculate different amounts of colloidal $Fe(OH)_3$. The upper line — very roughly — perhaps may represent the saturation values. This statement, however, according to MOOKHERJEE, is only a „much-too-oversimplified" view as the effect of other electrolytes and similarly or opposite charged colloides as well as their mixing rate is also very essential. We are in full agreement with the view mentioned above, namely, whereas in the samples of the Slope the relationship mentioned between P and Fe content is quite clearly seen, in a diagram plotted on the basis of P and Fe content of 115 samples from an other region, from the edge-part of shaft No. II, this relationship cannot be pointed out.

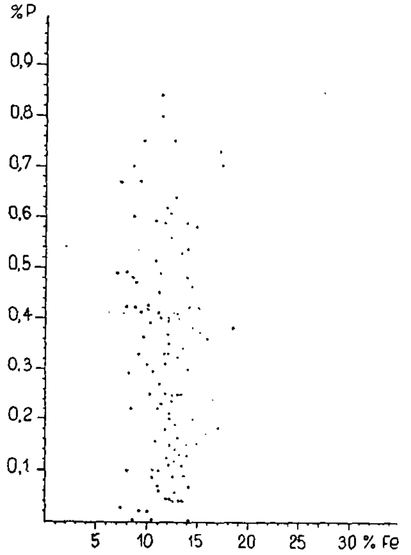

Fig. 25. Relationship between the P and Fe content of 115 samples from the edge-part of the shaft No. II.

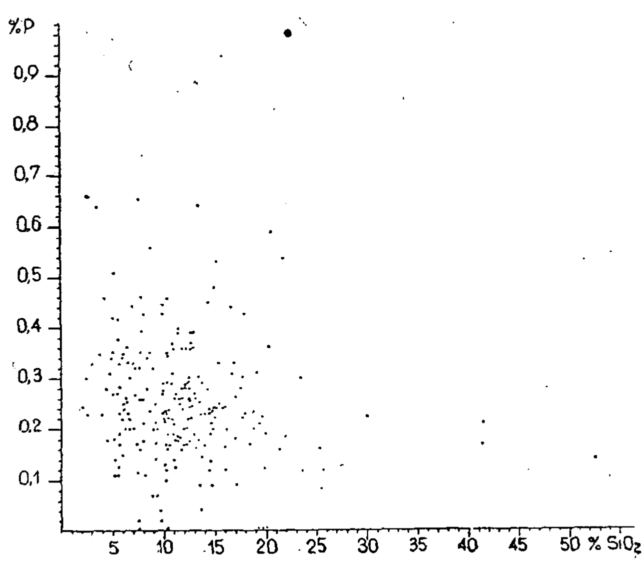

Fig. 26. Relationship between the P and SiO_2 content of 230 samples from the Slope.

Relationship can similarly be established between the P and SiO_2 content, however, for the time being, only in the case of the samples from the Slope. It is to be noted that similar relationship in the samples originating from the area of shaft No. II, again can not be established.

The detailed interpretation of the relationships between P—Fe and P — SiO_2 content — where they are valid — as well as the interpretation why this relationship exists in the area of the Slope but not in other areas, e. g., in that of shaft No. II, we intend to give in the future on the basis of further

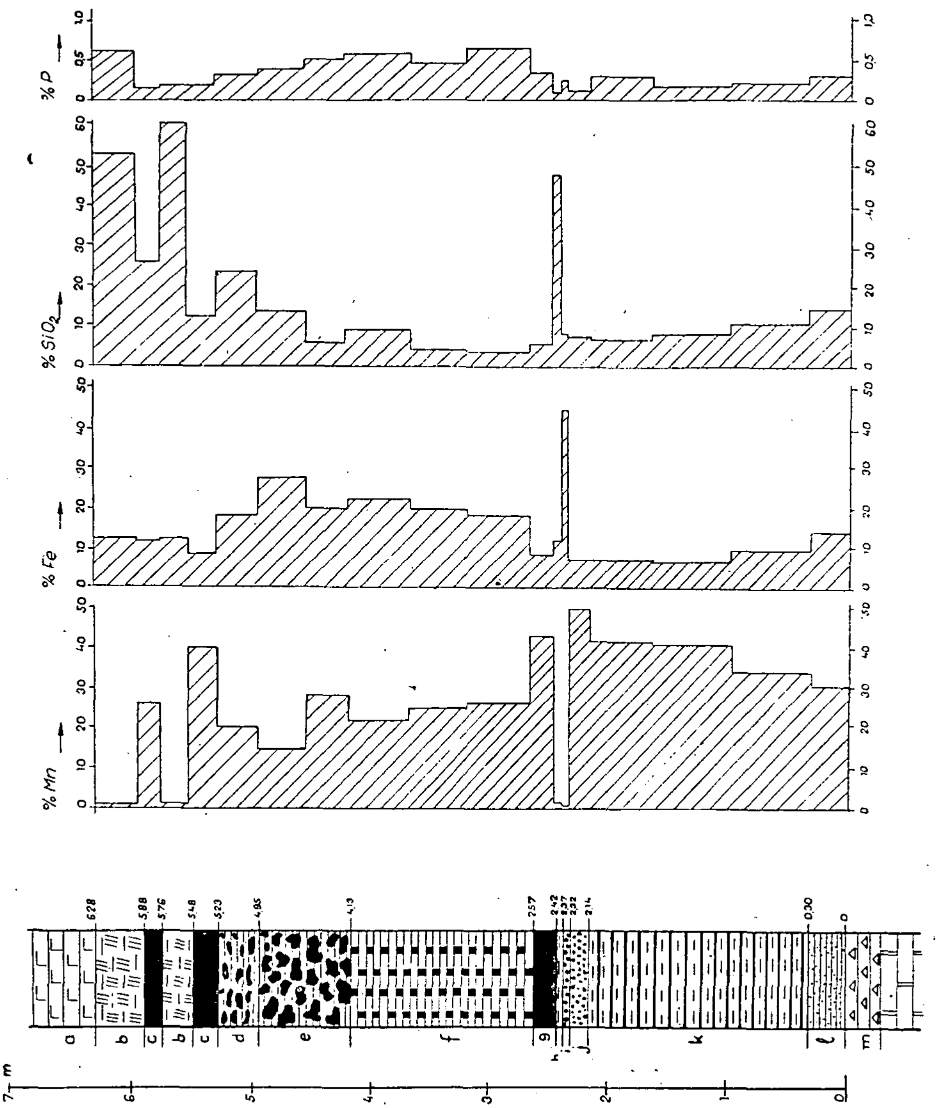

Fig. 27a. The change of the Mn, Fe, SiO_2, P content in the layers of the section

examinations in the field and model experiments in the laboratory.

It is to be noted that further relationship can be established between the P and Ca content of the samples. The Ca content increases with increasing P content. The clearness of this relationship, however, is blurred by the fact that the Ca content belongs not only to the calciumphosphate which is present in the samples possibly as fluorapatite mainly in very finelly distributed. The corresponding examinations under way are not limited to the area of the Slope but they refer to the whole area of Urkut.

The frequency distribution of the Mn, Fe, P and SiO_2 as well as the relationships between P — Fe and P — SiO_2 discussed above are valid for the whole area of the Slope. The question may arrise how far the same is seen in the case of the typical section examined in detail.

THE CHANGE OF THE AMOUNT OF SOME COMPONENTS IN THE CONSECUTIVE LAYERS OF THE SECTION DISCUSSED

The relationship valid for the whole area of the Slope in the section examined can also be established.

The phosphorus content downwards from the layer *c* gradually increases, then it decreases in general from the layer *g* though with smaller fluctuations. Parallel with this change, through the same layers, an increase of the Fe content can be seen and though not in any details, but generally is still observable the corresponding decrease of the SiO_2 content. Even in some layers this relationship can exactly be stated. Thus, e. g., in the clayey layer *h* the SiO_2 content is very high and the P content considerably decreases related to that of the over- and underlying layers. In the yellow, ferruginous layer *i* the increase of the P content can be stated corresponding to the increase of the Fe content.

The change of the carbonate CO_2, organic C and H_2O in the consecutive layers was also investigated. The results are plotted in Fig. 27b. The carbonate CO_2 content gradually increases from the top towards the layer *g*, then in the layer *h* reaches a relatively high value. Apart from this value and from the decrease to be established in the underlying layers *i* and *j*, the carbonate CO_2 content further increases towards the layer *k* and only in the layer close above the bedrock can some decrease be stated, however, the CO_2 content is still higher than in the upper layers. Where it was possible, the CO_2 content of the selected ore and the clayey material was separately determined. In the selected ore samples the CO_2 content was always higher than that of the clayey part which fact is presumably to be interpreted that the carbonate particles, inclusions in the oxide ore were protected from the dissolution and from the occasional oxidation.

The determination of the organic C content in the ores from Urkut up to day were not carried out or at least data referring to their organic C content were not published, although its determination seems to be essential from the point of view of the genese of the deposit, since an environment, rich in organic material, different circumstances for the deposition of the manganese may mean as an environment poor in organic material. Beside the determination of the organic C content of the single layers, the paleobotanical, pollen-analytical

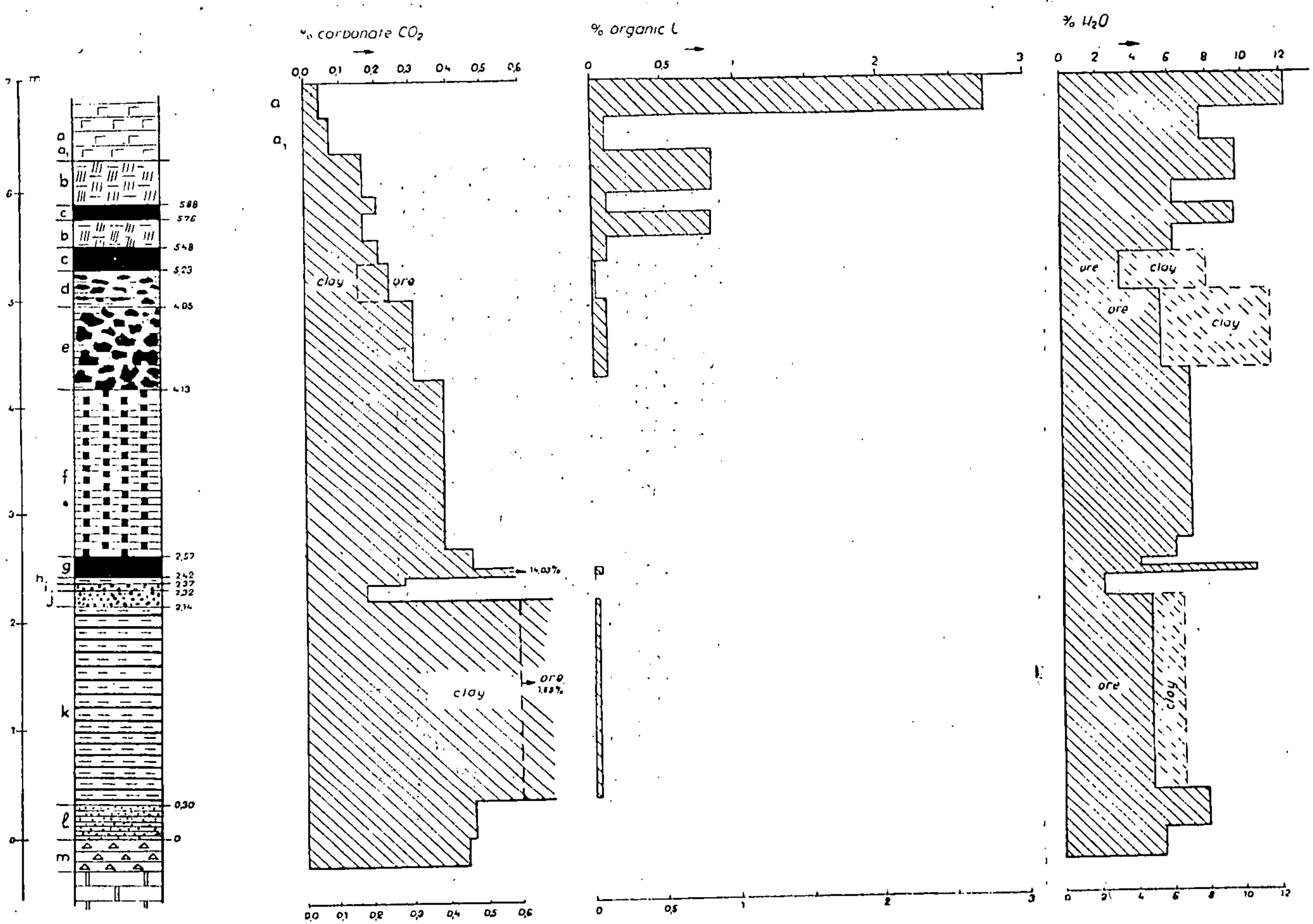

Fig. 27b. The change of the carbonate CO_2, organic C and H_2O content in the layers of the section

examination of the section discussed as well as further samples from other areas of the deposit were carried out by P. SIMONCSICS and M. KEDVES [1961].

The organic C content is extremely high in the dark gray, radiolarian clayey marl layer *(a)* and still considerable also in the green clayey *b* layer which fact well agrees with the results of the investigations of P. SIMONCSICS and M. KEDVES referred to as even in these layers were the most pollen and other relicts of plant origin to be detected and determined.

The organic C content after high values of the uppermost layers rapidly decreases, even in some layers was not to be determined. As in the case of the carbonate CO_2, the organic C content of the selected ore and the clayey part was separately determined. The organic C content within the same layers was higher in the selected ores than in the clayey parts. In some layers the organic C was absent or at least not present in determinable amount. This fact, however, does not mean that the layers in question do not contain traces of organic relicts, only the organic material is fully decomposed and only its silicified remnants can sometimes well be observed in thin sections. Thus, e. g., in the yellow „iron-sand" layer *i* only a minimal organic C content was to be determined, in thin section such a formation can be observed which possibly may be considered as of organic origin.

Fig. 28. Organic remnant in thin section from the material of the layer *i*. Plain light, ×100.

In thin sections made from the material of the bedrock (layer *m*, brown, cherty-striated clay) formations presumably of organic origin can also often be found: e. g. pollens, tube-like formations surrounded and partly also filled out by chalcedony both in length and cross-sections which may mean the places of former algal threads as well as branching formations which are presumably also of plant origin.

From the change of the H_2O content is to mention that the water content of the selected ore and clayey samples separately examined, where it was possible, the H_2O content of the clayey samples was higher.

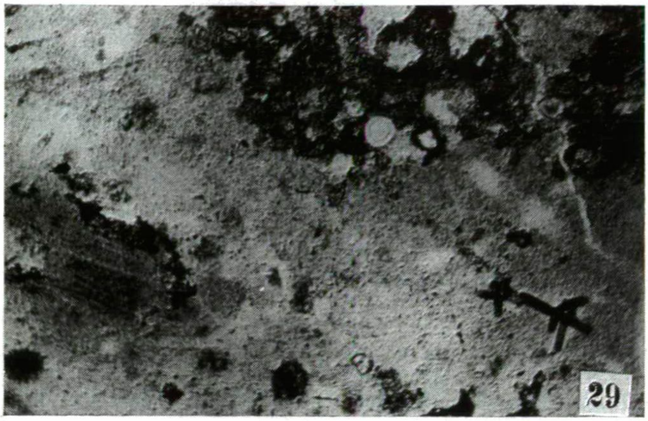

Fig. 29. Thin section from the material of the layer *m*. Organic remnants in opaline matrix; at right a branching formation possibly of plant origin. Plain light, ×50.

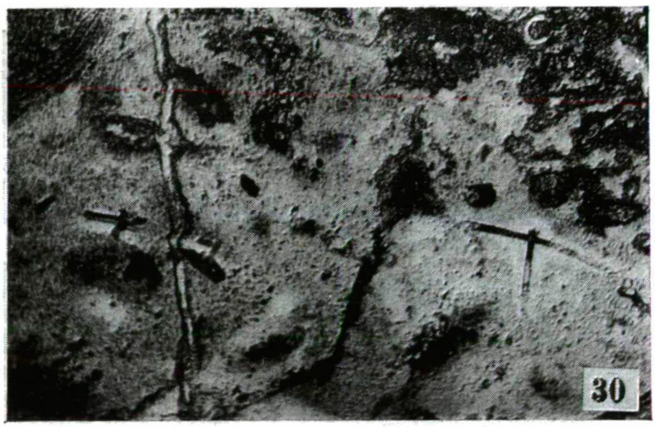

Fig. 30. Thin section from the material of the layer *m*. Branching algal tubes at right. The chalcedony surrounding the tubes mentioned in the text can also be seen. Plain light, ×50.

The study of other areas of the manganese deposit of Urkut on the basis of investigating the geological structure, the sequence of the different layers at different points, the composition of the layers, the mineral association as well as the frequency distribution of the major and some minor elements, further the paleobotanical investigation, in the concept of this paper, is under way.

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PALAEOBOTANICAL EXAMINATIONS ON MANGANESE SERIES IN URKUT (HUNGARY, TRANSDANUBIA)

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INTRODUCTION

The necessity of palaeobotanical examination of the manganese ore series in Urkut was raised by the result of the chemical studies reported by GRASSELLY and E. KLIVÉNYI [1960] in their preliminary publication. The theme promised to be interesting in respect of lacking publications of such examinations made in Hungary. The palynological research of this area is interesting from stratigraphic standpoint too, as the manganese series in Urkut originated from Upper Lias according to NOSZKY [1952], VADÁSZ [1952], SZABÓ-DRUBINA [1957] and CSEH NÉMET [1958], and a part of the beds was rearranged in period from Upper Jura to Middle Creta. In Hungarian relation the black coal bed in Komló originates from Lower Lias, its palynological examination was published by GÓCZÁN [1956].

In consequence of the examinations the following problems were arisen:

a) Is the origin of manganese series of Urkut from Upper Lias demonstrable on the basis of palynology?

b) Does the sporomorph spectrum show the rearrangement in Urkut?

c) Are there to be found some sporomorphs in Lower Liassic coal series of Mecsek (Komló) and in Upper Liassic manganese series of Urkut, which could be considered as common Jurassic, resp. Liassic characteristics, in spite of the differences existing between the developments and ages?

d) Does the manganese ore series include continental, shallow- or deep-sea, freshwater sediments?

To our mind the answer these questions will considerably contribute to the understanding of the chemical composition of the manganese ores, on the other hand to the palaeobotanical knowledge of the age in question respectively to the stratigraphy of the Hungarian Mesozoic era.

MATERIAL AND METHODS

We studied 47 samples on the whole, 17 out of them gave a total section, which is identical with the section worked up by *Grasselly* and *Cseh Németh* in his geological and mineralogical paper (Acta Miner. Petr. Szeged, 14, 1961). In our tables are the markings of the layers identical with the markings in paper of the above-mentioned authors. — The rest are single samples from the different part of the area. The samples were prepared by maceration in about 5 grams material. We began dissolve the manganese and decompose the carbonates by HCl and H_2O_2. After washing the samples were treated by the HNO_3, KOH and HF methods usually. The preparations were examined with oil immersion object glass, the photomicrographs were taken by 60× and 100× HI object glass and all are without retouch.

RESULTS

The samples containing the manganese and the loamy material with poor manganese contents are all rich in organic rests. All samples contain organic material in some form, but only few has sporomorphs in botanically well preserved condition. The intensive examination revealed abundant ensemble of microfossils.

The indicated microfossils, sporomorphs are discussed in succession of the natural system. In determination and identification of single sporomorphs we could not use the established nomenclature, as the Hungarian literature is deficient and the foreign literature has some different trends; therefore after identification we used the names given by the authors. We think it is the proper way lacking an established taxonomic procedure. Thus we don't deal with problems of nomenclature exceeding the limits of our work, though we shall refer to problems of nomenclature too, discussing the single forms.

SYSTEMATIC DESCRIPTION OF MICROFOSSILS

PROTOPHYTA

Cf. Algae **(Plate I., photos 1–8, Plate VIII. photos 21, 22).**

In some specimens rests are observable which are organisms without doubt but their origin is uncertain. We can distinguish 3 types:

a) Organism of spherical shape, about 6—8 μ in diameter, granular surface, size of the granules 0,7—1 μ, they are porelike formations, 2—4 μ in diameter. The observed specimens occur in groups always **(Plate I., photos 1—3 and 4—5).**

b) Organism, 5—8 μ sized, with irregular ornamentation, contour round or rounded ellipse. It was found in single granulae **(Plate I., photos 6—8).**

c) Spherical body, 10 μ sized, surface covered with numerous prickles (echinate), the base of the single prickle is wart-like, their length extends to 2 μ. This type presumably belongs to the *Hystrichosphaeridae* **(Plate VIII., photos 21—22).**

Hystrichosphaeridae

Specimens belonging to the *Hystrichosphaeridae* are to be found in small quantity in samples *a*, *b* of the rock-slope sections. We can distinguish two types on the basis of VALENSI's [1953] monography:

Micrhystridium recurvatum f. brevispinosa VAL. 1953 **(Plate I., photos 10–11 and 14, 15).**

Micrhystridium cf. *arachnoides* VAL. 1953 **(Plate I., photo 9).**

In DEFLANDRE's [1947] opinion *Micrhystridium* genus is to be found from Gotlandium to Creta, VALENSI [1953] found both genera in the Jurassic layers.

The oecology of the *Hystrichosphaeridae* can be pointed out as maritime or brack water environment according to the identical opinion of MATTHES [1956], BRELIE [1958], BRELIE and WOLTERS [1958], AVERDIECK [1958] and other authors. Their origin is uncertain, they can be ovules, planchtons, Dinoflagellatae, even spores.

Crassosphaeridae

These organisms were described by *Cookson* and *Manum* [1960] first. They published merely the new genus without establishing a separate category for this interesting and important group of microfossils. We consider the introduction of a new taxon is justified; their later systematization will be necessary, but on account of their deficient data we could not afford to accomplish it.

The relations of these microorganisms are uncertain, they are planchtons in all probability. In some samples one of the three differentiated species *Crassosphaera concinna* COOKSON and MANUM 1960 occurred consistently. The authors cited pointed out the difference between the *Tytthodiscus* NOREM 1955 and *Crassosphaera* COOKSON and MANUM 1960, i. e. the segmentation of the wall is characteristic of the former genus, while it does not occur in the latter one. We could not observe the segmentation in our specimens, so the determination of the genus is doubtless, but we hint at the fact, that the walls of our specimens are thinner than the walls observed by the above-mentioned authors. Moreover there are differences in some features between the Australian and Spitsbergean specimens according to COOKSON and MANUM [1960], in our opinion this is a reason for a new scheme of classification.. The forms examined are nearer to the Spitsbergean type.

Crassosphaera concinna COOKSON and MANUM 1960 **(Plate II., photos 1–6).**

Contour round or secondarily distorted, diameter 50–60 μ, surface densely covered with small projections, the pattern „resembling the cast of a honeycomb". In the centre of each projection these are little points, they are really the openings of the canals tending towards the centre, the wall is 3–4 μ thick.

Distribution: from the publication of COOKSON and MANUM [1960]: „Neocomian (on faunal evidence according to Island Exploration Co.'s Palaeontologist): Komenwu, Papua, New Guinea. I. E. C's well no 2 at 6840 ft. Lower Tertiary; Forlandsundet, Vestspitsbergen, 78° 40′ N–11°."

Stratigraphy: from Lias to Lower Tertiary.

Note: MACKO [1957] in his work compares the *Crassosphaera*-like micro-organisms and the recent *Diatomeae.* Our specimen mostly resembles to the *Stephanopyxis fuscus* JOUSÉ, described by MACKO in Lower Miocen, but this is only an external similarity and in our opinion it is an inadequate method to identify a Mesozoic form with a recent species.

MYCOPHYTA

The identification of the examined specimens belonging to this category is not possible. Spores of different types **(Plate I., photo 16, 17, 21),** conidia **(Plate I., photo 18, Plate X., photo 6)** and hypha threads **(Plate I., photo 20, 22)** were found. It is to note, that some fungus rests occurred on disorganized higher plant rests (cuticula), consequently we can draw the conclusion, that there were parasitic or saprophitic vegetations. As the quantity of the fungi rests occurred in direct ratio with the plant rest, the possibility of secondary contamination may be excluded.

PTERIDOPHYTA

Lycopsida

Lycopodiumsporites clavatoides COUPER 1958 **(Plate III., photo 19 and Plate VI., photos 7—11).**

Spores trilete, laesurae not always distinct. Surface reticulate, size range of reticulum 4—15 μ, thickness of the ridges (muri) 0,5—2,5 μ, their length 5 μ maximum. Wall of the spores 1—2 μ thick, the wall-hyalin under the reticulate thickening is smooth or minulety chagrenate. Maximum diameter 35—50 μ, measured together with the height of the ridges.

The spores shown in the figures are similar to the spores of GÓCZÁN [1956], belonging to the *Lycopsida,* from Lias of Mecsek, which are similar to the forms of ROGALSKA [1954]. Our spores are in agreement with the Middle Jurassic sporeforms, published by COUPER [1958]. Otherwise COUPER [1958] points out, that the age of the spores is the period from Jura to Lower Creta.

Pteropsida
Schizaeaceae

Leiotriletes pflugi n. fsp. **(Plate III., photos 1,2; 3,4; 5,6; 7,8; 9; 12, 13).**

Diagnosis. In polar view rounded-triangular trilete spore. Laesurae of the tetrad scar long, but don't reach always the equatorial contour, r = $^4/_5$ — $^5/_5$, exosporium 2—3 μ thick, chagrenate, intrapunctate or inragranulate. Striae-like structure is observable too, presumably in consequence of secondary transformation. Diameter 28—45 μ.

Holotype: **Plate III., photos 1,2.**

Stratigraphy: it is known only from the Lias.

The spores described under the above-mentioned denomination are in their different preservations like some fsp. of the *Poroplanites* genus of PFLUG [1953], regarding the triplanity. H. DEÁK [1959], and KEDVES [1960, 1961], in their publications dealing with the trilete, triplanoid and triplan shape-transformations pointer out, that the triplan, triplanoid forms are preservation states of the trilete spores. BOLKHOVITINA has the same opinion too (verbal information), moreover in her mind the trilete spores having lost their perisporia turn into triplans generally. Her opinion is based on numerous recent examinations. The fossil trilete forms and the triplans are contracted by many other authors too. KEDVES [1961] expressed his opinion in this regard minutely in his paper about the spores of the coal basin from Sparnacian stage of Dorog. Concerning the pores of the genus *Poroplanites* PFLUG 1953 we note, that neither we nor GÓCZÁN observed pores on these forms in Hungarian Lias. COUPER'S [1955] opinion is, that the pores of these forms are differentiations in consequence of mechanical effects and in contrast with PFLUG [1953] he attaches no phylogenetic importance to these, moreover he considers impossible to admit the relationship of *Poroplanites* PFLUG 1953 to the *Angiospermae* or angiospermid. As our spores apart from the pores, are similar to *Poroplanites porosinuosus* PFLUG 1953, we denominate our forms *Leiotriletes pflugi,* expressing our appreciation to the excellent palynologist. Our forms are similar to REISSINGER'S [1950] „*Vermutliche Farnspore*" called spores (Tafel XII., Fig. 14—16) and to some forms of GÓCZÁN'S „*Farnspore Type 4/d*" and „*Farnspore Type 5*" from Lias of Komló.

We observed the following form variations within the form species:

Leiotriletes pflugi n. fsp. asp. *triplanoid* n. asp. **(Plate III., photos 3—4, 9).**

Diagnosis: slightly triplan spore, the size-difference of the axis is not significant.

Holotype: **Plate III., photos 3, 4.**

Note: The described specimen is very much like the spores placed by PFLUG [1953] in the *Poroplanites* (*P. porosinuosus* PFLUG 1953).

Leiotriletes pflugi n. fsp. fvar. *triplan* n. fvar. **(Plate III., photos 5, 6, 7, 8).**

Diagnosis: extremely concave in polar view, the pole-axis is longer than the equatorial axis. The three lobes are well observable in any case.

Holotype: **Plate III., photos 5, 6.**

Note: As this form frequently occurs, we suppose, that the further palynologic examinations of the Liassic age will enlarge the form-variations.

Affinity: Presumably *Schizaeaceae*, cf. *Lygodium.*

The **photos 12, 13 on Plate II.** represent strongly compressed specimens, such forms, which are varied, depending on the direction of the compression and which are not characteristic, we can not regard them as special form-variations.

Cf. Schizaeaceae

Punctatisporites rotundus WEYLAND and GREIFELD 1953 **(Plate IV., photos 17, 19).**

We found it in one specimen with 47 μ diameter, the dehiscentia lines run to $^{2}/_{3}$ of the radius. Exosporium granular, wall 1,5—2 μ thick. WEYLAND and GREIFELD [1953] (in KREMP, AMES and HILDE GREBE [1957]) found the size 45 μ, but we think that the minimal difference between the size of the spores can not prevent the identification.

Stratigraphy: Lower Creta, Upper Senon according to the authors, Lias according to our examinations.

Affinity: It is not given by WEYLAND and GREIFELD [1953] (in KREMP, AMES and HILDE GREBE [1957]), but our observations on recent material justify the belonging to the mentioned family, but it is uncertain and for this reason we use as category cf. *Schizaeaceae.*

Trilites verrucatus COUPER 1953 f. *minor* n. f. **(Plate V., photos 5, 6; 7, 8; 9, 14).**

Description. Contour round or strongly rounded triangle in polar view. Laesurae of the tetrad scar are long, r = $^{4}/_{5}$—$^{5}/_{5}$, exosporium about 2 μ, sculptura verrucate, height of the warts here and there reaching 2 μ, the average 1 μ generally. The warts may form here and there pseudo-reticulum. The description of the spore published so far is in accordance with the *Trilites verrucatus* COUPER 1953, but the size of our spores doesn't reach the size given by COUPER [1953], i. e. 35—(42)—51 μ and so we consider it as a new form.

Diagnosis: 20—(25)—30 μ sized spores within the form species, which agree in sculpture and in other features with the diagnosis given by COUPER [1953] and respectively with our description followed partly COUPER's data.

Holotype: **Plate V., photos 5, 6.**

Stratigraphy: According to COUPER the fsp. originates from Creta and on the basis of the geological results our specimens are Jurassic (Liás). Maybe, that the difference between the data published by COUPER and our spores are showing a developement line, perhaps our small specimens are spores of the ancestral types of the fossile fern-species and the Cretaceous spores are more developed. Naturally the geographical difference can produce such variations and our above-mentioned supposition is obvious on the basis of morphological agreement and difference of the ages, but we don't regard this question as settled.

In COUPER's [1953] opinion the affinity is unknown but according to the available data no definite affinity can be proved, however, we suppose an affinity with the *Schizaeaceae.*

Punctatisporites fsp. **(Plate V., photo 13).**

Fragmentary form, surface punctate, here and there granulate, however it is doubtful whether the observed structure is original, or the result of the corrosion. Maximum diameter 32 μ, laesurae extending almost to the equator, shape streched ellipsoid, presumably owing to the compression.

In all probability the spores shown on the Plate V., photos 18—19, belong to this form-genus, but the laesurae are uncertain, the thickness of the exosporium is about 1,5 μ, having intragranulate and rugulate structure, at any rate the secondariness of the structure holds good as in the former specimen.

Affinity on the basis of the preceedings presumably *Schizaeaceae.*

Cf. Gleicheniaceae

Undulatisporites fsp. **(Plate V., photos 11—12).**

Triangle spore, rounded in polar view, diameter 30 μ. Laesurae on the tetrad scar opened, so the features can not be well determined, nevertheless its vawy running is doubtless. Near the laesurae a torus-like formation is seen, this however may be secondary due to the deformation. Surface of the exosporium granulate, sculpture not well observable.

Affinity: presumably *Gleicheniaceae.*

Cyatheaceae

Cyathidites minor Couper 1953 **(Plate IV., photos 9, 10).**

The observed specimen is maximum 38 μ, tetrahedric spore, equatorial contour rounded triangle, side-lines straight or slightly concave. Laesurae of the tetrad scar reaching almost the equator, there is a torus apparently, due to the opening of one laesura. Spore wall chagrenate, ornamented, thickness to 1,5 μ.

Couper [1958] points out as affinity *Dicksoniaceae* besides *Cyatheaceae* and the distribution from Jura till Lower Creta in Englend.

Cyathidites minor Couper 1953 asp. *triplanoid* n. asp. **(Plate III., photos 10, 11).**

Diagnosis. Laesurae straight, reaching the equator, with narrow margin. Thickness of the exosporium 1—1,5 μ, the wall obviously two-layered, internal spore-wall chagrenate. The form is compressed towards the triplanoid and the sidelines of the equatorial contour became convex.

Holotype: **Plate III., photos 10, 11.**

Affinity: As the spore is in all probability the triplanoid form of the *Cyathidites minor* Couper 1953, it may be considered on the basis of the abovementioned facts, as the *Cyatheaceae* or *Dicksoniaceae.*

Stratigraphy: in all probability corresponds to the *Cyathidites minor* Couper 1953.

Sporites incertae sedis

Toroisporis transdanubicus n. fsp. **(Plate IV., photos 11, 12).**

Diagnosis. Equatorial diameter 35 μ, contour triangle with rounded vertices, straight or slightly concave sides. Laesurae don't reach the equator, r = $^4/_5$. The scar „Y" is associated with a narrow torus, maximum breadth 3 μ. Sporewall on the corner 2 μ, in the middle of the sidelines minimum 5 μ; they are two-layered on the corner and seems to be composed of more lamellae in the middle of the sidelines. Ornaments of the lamellae are not distinct, structure not more rough than the chagrenate, however, the innermost lamella is punctate probably.

Holotype: **Plate IV., photos 11, 12.**

Stratigraphy: according to the last results only from Lias.

Distribution: manganese ore series in Urkut.

Note: The described new fsp. shows similarity to the fsp. of the *Toroisporis* (*Divitoroisporis* KRUTZSCH 1959) subfgen., published by KRUTZSCH [1959] from the Tertiary, but it differs by structure and size range of the exosporium, the gaping of the laesurae is absent or merely a „pseudodivisus" form is present.

We can consider the sporomorphs on the **Plate III., photos 16—18** belonging to this group too, but the thickening of the side-lines is here doubtful and the laesurae seem to reach the corners in consequence of the spore deformation. Therefore we designate them with cf.

Polycingulatisporites n. fgen.

Fgen, type: *Polycingulatisporites circulus* n. fsp.

Diagnosis: Contour round or rounded triangle. Two ± concentric rings appear on the spore in proximal view, in most cases with wavy or dented course. The laesurae of the tetrad scar are distinct in polar view.

Note: The new fgen. differs from the known fgen. of the *Zonotriletes* (WALTZ 1935) R. POT. and KRP. 1954., by interesting morphological features.

Polycingulatisporites circulus n. fsp. **(Plate VI., photos 1—6).**

Diagnose: Spore round or ellipsoid. Maximum diameter 35—50 μ. The external zone 3—5 μ broad in proximal view, surface striate minutely, the structure elements are arranged in radial direction. The dividing line between the external and internal zone wavy, striate like the former, however, the structure is here not so distinct. The central body is nearly a rounded triangle with a smooth surface. The laesurae of the tetrad scar may be slightly wavy and enter in to the external zone, then bifurcate forming an obtuse angle. Distal pole smooth, but the characteristic structure in form of concentric rings is well observable.

Holotype: **Plate VI., photos 1—6.**

Note: Our form described above is so characteristic of and different from the known spores of the *Zonales* (B. and K. 1886) R. POT. and KRP. 1954., that we wish to raise some questions concerning their morphology. As in *Cingulatisporites* TH. 1953., *Polypodiaceoisporites* R. POT. 1956, non 1951, in *Camerozonosporites* PANT 1954 and in other formgenera the zones are always well definable and well separated from the central body, so we cannot say the same about our new formgenus. The zonal morpohology of the external sphere seems to be doubtless, but doubts may arise concerning the internal zone as the real spore — the central body is of minimal size related to the whole of the form. Therefore it is presumable that the central body is separated into two parts inside the zone. This possibility is not out of question, at any rate the concept mentioned above seems to be reasonable at least on the basis of the data available in the literature. We hope the following examinations will contribute further informations to the knowledge of this very interesting spore.

Perotrilites pseudoreticulatus COUPER 1953 **(Plate V., photos 1—4).**

Well preserved specimen, its morphology is suitable for exact examination on proximal and distal poles. Diameter 35 μ, on the proximal pole ornamented with minute, irregular, not reticulate sculpture elements, the prominences are stronger and more distinct on the distal pole. The ridges 1 μ broad, 1,5—2 μ high. Wall thicker than 1 μ. Laesurae of the tetrad scar slightly wavy in polar view reaching almost the equator, $r = {}^{4}/_{5}$.

Stratigraphy: Jura in opinion of author.

Affinity: uncertain.

Corrugatisporites arcuatus WEYLAND and GREIFELD **(Plate V., photos 16, 17).**

The spore is fairly compressed and fragmentary specimen, however the essential features are well recognizable with oil-immersion object glass. Size 45 μ, somewhat smaller than measured by the above-mentioned author, contour ellipsoid, secondarily altered in consequence of compression. Laesurae reach the equatorial contour, though this in not always to be seen on account of the secondary alteration. Sculpture corrugate, respectively verrucate, sculpture elements 2 μ maximum.

Stratigraphy: Lower Creta, Upper Senon according to the authors.

Affinity: unknown.

Leiotriletes fsp. **(Plate III., photos 14, 15).**

Spore trilete, diameter 28 μ maximum, equatorial contour rounded triangle, little compressed distal pole hinders the exact determination of the spore. Spore-wall two-layered, the layers are a little thinner than 1 μ, laesurae reach about the equator.

Cyatheacidites fsp. **(Plate V., photos 10, 15).**

Fragmentary specimen, zone with expressed wavy contour and sculpture. Height of the sculpture elements may reach 3 μ, breadth 2—5 μ. The central body seems to be smooth and has poor structure, diameter about 25 μ, laesurae of the tetrad scar are clearly observable and run to the margin of the central body. Diameter maximum 32 μ.

In the following part we describe spores of unknown, or uncertain form-genera.

Pteropsida spore indet., *type „A"* **(Plate IV., photos 1, 2).**

Diameter 32 μ, in polar view triangle. Tetrad scar obscure, however its presence is sure. It has a charasteristic formation on the corners, which reminds in some features of the Obtusi-apparate (PFLUG 1953), though does not quite correspond to it. It is interesting and possible that this form will later have great importance in phylogenetic point of view, because a formation is visible on the corners, bearing resemblance to the germinal-apparate of the *Angiospermae*'s pollen. As this formation is obscure, we attach no importance to it, but possibly we shall be able to observe later the primitive type of the ancestral

Angiospermae pollen in well preserved material. The spores shown on **Plate IV., photos 3, 4 and 5, 6** belong presumably to the same type, though the obscure germinalia on the latter photos are not to be seen.

Pteropsida spore indet., *type „B"* **(Plate IV., photos 7, 8).**
Equatorial diameter maximum 27 μ. Equatorial contour triangle with obtuse angle. Exosporium about 1 μ thick, chagrenate. Laesurae of the tetrad scar reach the vertices. Spore shows similarity to the *Cyathidites minor* COUPER 1953, but is smaller and granulated more minutely. The form on **Plate IV., photos 15, 16 and 18** belongs to the same category, but the walls are little stronger.

Pteropsida spore indet., *type „C"* **(Plate IV., photos 13, 14).**
Maximum size 30 μ. Equatorial contour rounded triangle in polar view. Laesurae obscure, reaching almost the equator. Spore wall thicker than 2 μ, ornamentation intrapunctate or intragranulate, not determinable exactly.

Cf. Pteridophyta spore **(Plate V., photo 20).**
Few specimens of diameter 70 μ maximum, not well preserved for exact determination; the form reminds of spore, the adherent opaque material does not shade the coarsely granulated surface. Uncertain remains like our specimens: *Sporites macroserratus simplex Wolff* 1934 (in KREMP, AMES and KOVAR [1958]), and the specimen denominated *„Siegelsum R-type"* by PFLUG [1953].

GYMNOSPERMAE

Pteriodspermae

Caytoniales

Caytonipollenites pallidus (REISSINGER) COUPER 1958 **(Plate I. photos 26, 27).**
Pollen with air-bladder, found in one specimen, wall very thin, body elongated, sculpture of air-bladder reticulate minutely.
Affinity: in all probability *Caytoniales;* REISSINGER describes [1950] it as *Pityosporites pallidus* and in his opinion is similar to *Podocarpaceae.*
Stratigraphy: from Jura to Lower Creta according to COUPER [1958].

Pteruchipollenites cf. *thomasii* COUPER 1958 **(Plate X., photos 1, 4).**
The observed specimen is strongly fragmentary, size maximum 35—40 μ, the body is surrounded by air-bladders halfmoon like. We note in connection with the structure, that its exact determination is impossible being distorted strongly.

Cycadinae v. Ginkgoinae

Monosulcites minimus COOKSON 1947 ex *Couper* 1958 **(Plate VII. photos 1—21).**
This pollen is frequent in Jurassic, generally in Mesozoic layers, it was found in numerous layers, e. g.: LANTZ [1958 a, b], COUPER [1958], GROOT

and PENNY [1960], etc. Similar forms are *Encephalarites cycadioides* ZAKLINSKAJA 1957 (pollen) described by ZAKLINSKAJA [1957] (in KREMP, AMES and KOVAR [1958]) and *Ginkgo bilobaeformis* ZAKLINSKAJA 1957 (pollen) too. KEDVES [1961] in his work regarding the pollen of *Ginkgo biloba* L. deals with this problem minutely, we refer here to some important data: LANTZ [1958] compared the *M. minimus* COOKSON [1947] ex COUPER [1958] with the pollen of cf. *Ginkgo biloba* L., named in the work of ROGALSKA [1957]. The observed fossil forms compared with the pollens of the recent *Ginkgo biloba* and the different genera of *Cycadinae,* the affinity with the *Cycadinae* is more likely, though the affinity with the *Ginkgoinae* can not be excluded, all the more as the problem of the systematic affinity of the Mesozoic pollens is to be carefully treated.

The observed specimens are 21—34 μ long, sulcus (colpus) assymmetrical, ectexine 1—1,2 μ, smooth, but we found intrapunctate, resp. intragranulate specimens too. These slight structural differences cannot be considered as essential features, partly owing to the observations made on the recent *(Ginkgo biloba* L., *Cycadinae)* pollens, partly owing to the secondary alteration, often observed in our examinations on fossil material.

Monosulcites urkutiensis n. fsp. **(Plate VII., photos 24—27).**

Diagnosis: Yellow or yellow-brown, ellipse-shaped pollen. Length 18—20 μ, ectexine 1—1,5 μ, surface chagrenate minutely. Sulcus does not reach the two apices of the pollen and often shows gaping.

Note. It differs by the small size and the smooth or slightly structured surface from the morphological related *M. minor* KEDVES 1961, *M. tranquillus* (R. POT.) TH. and PF. 1953, *M. zievelensis* PF. 1953 and *M. minimus* COOKSON 1947 ex COUPER 1958.

Affinity: problematical, presumably *Cycadinae,* but the different taxons of the *Monocotyledones* can not be left out of question.

Within the fsp. two subfsp. can be separated:

a) subfsp. *hyalinoides n. subfsp.* **(Plate VII., photos 24—26).**

Diagnosis: ectexine hyalin smooth, thickness 1 μ, sulcus does not reach the apices generally.

Holotype: **Plate VII., photos 24, 25.**

b) subfsp. *scabratus* n. subfsp. **(Plate VII., photo 27).**

Diagnosis: ectexine chagrenate, thickness 1—1,5 μ, sulcus reaches the two apices generally.

Holotype: **Plate VII., photo 27.**

Cf. Coniferae

Classopollis torosus (REISSINGER) COUPER 1958 **(Plate IX., photo 1—25.)**

Flattened, spherical pollen, sometimes impressed on the poles, obscure tetrad scar on the proximal pole, pore on the distal pole not always discernible. The general feature of the pollen is a characteristic zone around the equator, which consists of 4—8 striae, breadth of the zone 5—10 μ. The pollen-wall on other places is intrabaculate generally, but the baculae are here and there arranged in bands, forming zones, even the bands in equator are dissolved in some places, forming inward standing baculae, which phenomenon presumably depends on the state of preservation.

Polar axis of the pollen 20—25 μ, equatorial diameter 26—40 μ. Exine composed of many lamellae. The lamella „a" of the ectexine is smooth, the lamella „b" is baculate, the external one is smooth. Baculae are smaller than 1 μ.

The surface of the pollen becomes „wrinkled" here and there, reminiscent of the colpi or cavernae, even geniculuslike differentiation may be formed.

We saw them in large quantities in sample no. 3. On the basis of the examinations of many specimens we agree with COUPER [1958] in the opinion, that PFLUG [1953] described variants of the same plant using different terms. The uncertainty of the above-mentioned determination — it is essentially adequate to the described species — and the diversity of formvariations of the found sporomorphs makes possible the differentiation of the sporomorphs, however we are convinced, that the pollens in question belong to a single species.

Affinity: uncertain in COUPER's opinion [1958], KENDALL's supposition, that the pollen belongs to the Araucariaceae is not proved, neither on the basis of the pollen-analyse, nor on the basis of the epidermis-studies of *Pagiophyllum connivens* KENDALL (Middle Jurassic plant, to which this pollen belongs). That it belongs to the *Coniferae* is likely, although THIERGART [1949] describes similar form as *Bennettites* pollenites.

Stratigraphy: According to COUPER's [1958] examinations it occurs from Jura to Lower Creta in England, PFLUG [1953] described the synonym *Classopollis classoides* PFLUG, the *Circumpollis phariseus* PFLUG 1953 and the *C. philosophus* PFLUG 1953 from the Lias of Siegelsum, the *Classopollis declassus* PFLUG 1953 from Lias of Wehmingen, the *Classopollis maturus* PFLUG 1953 from Lower Senon of Quedlinburg.

Coniferae

?? Taxaceae

Spheripollenites subgranulatus COUPER 1958 **(Plate VII., photos 28—39, Plate VIII., photos 1—15).**

These pollens could be well examined in our material, as they occurred abundantly in our samples, rich in pollens. Our forms are in full-agreement with the diagnosis, described by COUPER [1958], the porus hardly differentiable, is well discernible in some of our specimens. Sometimes they occur in groups **(Plate VII., photo 36),** or they are stuck together in pairs **(Plate VII. photos 37—39).** The structure is less observable in some cases on fragmentary specimens. Regarding their systematical affinities COUPER [1958] ranges it in the group Incertae Sedis and he supposes only the possibility of an affinity with the *Taxaceae.* On the basis of our present knowledge they belong probably to the *Gymnospermae,* but their closer affinity is unknown.

The case is similar to the *Spheripollenites* scabratus COOKSON 1958 **(Plate VIII., photos 16, 23),** described by COOKSON [1958], well differentiable due to its structure and greater size.

Uncertain affinities have the *Inaperturopollenites parvoglobulus* WEYLAND and GREIFELD 1953, described by *Weyland* and *Greifeld* [1953] (in KREMP, AMES and HILDE GREBE [1957]) **(Plate VIII., photos 25 and 31—37)** and the

I. globulus WEYLAND and GREIFELD 1953 **(Plate VIII., photos 38, 39).** They are interesting forms, whose belonging to the Pteridophyta can not be regarded as out of question, however their belonging to the Pollenites, according to the authors, is more likely. Theier relatively strong structure is characteristic of the ectexine and for that reason its identification as *Coniferae* is uncertain. We can not take sides definitely in this question as the literature is deficient and we could not examine these forms thoroughly, on account of their infrequent occurence.

ANGIOSPERMAE

Eucomiidites troedssonii ERDTMAN ex COUPER 1958. **(Plate VIII., photos 17, 18.)**

COUPER [1958] measures the polar diameter 28—(35)—42 μ, our pollen observed has 25 μ diameter. As other features entirely agree with the described froms, so the identification is without doubt. Its presence is very interesting, it originates probably from ancestral *Angiospermae* pollen, in ERDTMAN's opinion.

We observed some specimens of pollens of higher *Angiospermae,* which were inwashed or rearranged certainly and belong to this class in all probability. We list them too for the sake of completion.

Cf. Nymphaeaceae

Pollenites pseudohirsutus DOKT.-HREBNICKA ex PACLTOVÁ 1960 **(Plate VIII., photos 26—29).** The observed specimens have 16—18 μ diameter, surface ornamented with narrow, about 1,5—2 μ long prickles, thickness of the exine under 1 μ generally.

Cf. Ranunculaceae pollen **(Plate VIII., photos 24, 30).** Diameter 15 μ, nearly spherical pollen, surface ornamented densely with 2—2,5 μ prickles (echinate), which are broadened on their basis (2—3 μ).

Magnoliaceae

Monocolpopollenites indet. **(Plate X., photos 7, 8).**

67 μ long ellipsoid pollen. Sulcus (colpus) hardly observable, assymmetrical, perhaps by secondary alternation in consequence of fossilization. Surface structured, not well observable owing to the corrosion and contamination, but it is ornamented, intragranulate, intrarugulate, respectively as we were able to observe in spite of the hindering factors.

Cf. Compositae pollen **(Plate I., photos 23—25).**

We observed only one fragmentary specimen, which originates from a plant belonging doubtlessly to the *Compositae* according to ERDTMAN [1952], WANG [1960] and STIX [1960]. Regarding the age of our samples the specimen is undoubtedly allochton, possibly it is subfossil (recent) contamination.

Fagaceae

Tricolporopollenites cingulum (R. POT.) TH. and PF. 1953 subsp. *pusillus* (R. POT.) TH. and PF. 1953, *Tricolporopollenites cingulum* (R. POT.) TH. and PF. subsp. oviformis (R. POT.) TH. and PF. **(Plate VIII., photos 19, resp. 20).** Both forms are in affinity with the recent *Castanea* genus, their abundant presence begins in Lower Tertiary, it is a rearranged form too, inwashed from Lower Eocen probably.

Monosulcites indet. **(Plate VII., photos 22, 23).**

Only one specimen observed, length 23 μ, sulcus not to be seen well, surface granulate, resp. rugulate. This structure is characteristic rather of the *Palmae* pollens. It is to note here, that the presence of the *Palmae* in Jura is doubtful, but the occurrence of this pollen may be explained with the rearrangement, described by SZABÓ—DRUBINA [1957] and CSEH NÉMETH [1958], authors mentioned in the introduction of our work. It is of interest to note, that PACLTOVÁ [1961] indicates *Palmae* pollens in Senon, which determinations are right, being about 130 recent *Palmae* pollens identified according our observations and so the presence of the *Palmae* in Upper Creta is presumable.

Tissue fragments.

The tissue fragments are frequent both in the loamy and in the manganese ore containing samples. There are to be found parenchyme **(Plate X., photo 2)**, tracheide **(Plate X., photo 3)**, cuticular **(Plate X., photo 6)**, epidermoid **(Plate X., photo 9)** fragments, fossil tissue elements of high developed vascular plants. The determination of the plants is impossible on account of the deficient characteristics, but their presence is important owing to the carbon, phosphorus and sulfur content of the manganese ore.

Artificial products **(Plate I., photos 12, 13).**

In the preparations there are pretty frequently green-yellow little balls of different size with irregularly dispersed pores on their surface reminiscent of *Algae*. They can be experimentally produced from glycerine and aceton film solution and they adsorb the colouring agent of the sample. The cell group shown on **Plate I., photo 19** bears resemblance to them, but can not be considered to be artificial product; it seems to be composed of different individuals of smooth surface, like zooglea, their preservation in our opinion is due to their adhering to one, even to two cuticles.

DISCUSSION

On the basis of our investigations we can not give definitive answer to the raised problems in every respect. The reason is not the imperfection of the methods, but merely the fact, that out of the 45 samples only two were valuable for palynological examinations. Some useful conclusions can be drawn from the spectrum **(fig. 1)** of samples deriving from the baring and from the oppermost layer of the bed.

a) Regarding their age we could determine on the basis of the stratigraphic statements of COUPER [1958], PFLUG [1953], WEYLAND and GREIFELD [1953] (in KREMP, AMES and HILDE GREBE [1957]) etc.'s statements stements, that our sporomorphs existed in England and Germany from Lias to Lower Creta. We found but few pollens (see *Angiospermae)* typical in Tertiary and which does not fit into the Liassic — Lower Cretaceous spectrum. We referred previously, in connection with the *Compositae* pollen to the probability of their origin from the subsequent contamination.

According to the present data the *Crassosphaera concinna* COOKSON and MANUM 1960 found in Spitsbergean Tertiary, is unfitting into the age, though *Crassosphaerae* are known in the Neocom too. The *Crassosphaera* genus was discovered in our days, its stratigraphy — as our data prove — surpasses the short time and space described by COOKSON and MANUM (1960) and their distribution was general from Ney Guinea to Spitsbergen, according to the present records.

Most of our forms prove the age to be from Lias to Lower Creta but they don't suggest a shorter period.

b) From the sporomorph ensemble described above, may be drawn such a conclusion that gives the answer to our second problem referring to the rearrangement of the layers. In so far as we found merely few sporomorphs inadequate to the Mesozoic in the barring and the uppermost samples of the layer, we have to ascertain, that the upper limits of the rearrangement did not pass the bed, respectively the Lower Creta.

The used literature locates most of the forms in Lias, resp. Lower Creta: by reason of the two spectra we could separate neither Lias, nor Dogger, nor Lower Creta; we must be confined merely to the negation of an age, which was older than Lias and younger than Lower Creta.

c) As the stratigraphy of the sporomorphs ranges in large intervals, many of our forms agree with the forms opened up from Liassic hard coal in Mecsek. GÓCZÁN [1956] disposed of less literature than we do now, therefore he named his form with a „nomenclature" of his own. We think it is not competent to draw comparison between the sporomorphs of Lias in Mecsek and of Upper Lias — Lower Creta in Urkut making use of the photos of many fairly corroded specimens. Some identity is shown in the following table:

Urkut	Mecsek
Lycopodiumsporites clavatoides COUPER 1958	*Lycopodites sp. (=Reticulatisporites sp.) (1 type)*
Cyathidites minor COUPER 1953	*Phlebopteris münsteri* (SCHENK) HIRM. et HOERH. *(4 type)*
Leiotriletes pflugi n. fsp.	*Farnspore (4/d type)*
Spheripollenites subgranulatus COUPER 1958	*Sporites* sp. *(13 type)*
Caytonipollenites pallidus (REISSINGER) COUPER 1958	*Pityosporites pallidus* (REISSINGER) *(Podocarpaceae?) (16 type)*
Pteruchipollenites cf. thomasi COUPER 1958	*Pinus haploxylon* RUDOLF

Naturally the Lias in Mecsek is more abundant in sporomorphs than the two samples of the manganese ore layers in Urkut, but the oecological conditions must have been different in the region, where the hard coal of Mecsek developed, as in Urkut.

d) Regarding the great variety of species, the *Pteridophyta* is firstly to be mentioned among the identified sporomorphs. Considering quantitative data, *Spermatophytae* are prevalent. They all are of continental origin. There are, however three forms (in both samples), all indicating — besides many continental forms — the sea-sediment origin of both samples. These are: *Micrhystridium recurvatum* f. *brevispinosa* VAL. 1955 and *M.* cf. *arachnoides* VAL. 1955. In the authors opinion both are Jurassic rests, characteristic of maritime sediments. The third form *Crassosphaera concinna* COOKSON and MANUM 1960 is also of maritime origin. In spite of the insignificant quantity the conclusion can be drawn, that the samples *a* and *b* originate from sea-, or half-salt water sediment, the spores and pollens were transported from a short distance, by water or air-way. We suppose the parent plants lived on sea-shore, which shed their pollens and spores into the sea, where they were fossilized in good condition, cut of from the atmospheric oxygen. In our samples few forms occurred in corroded condition, which fact contradicts the long transport.

Conclusively our samples *a* and *b* originate from shallow sea and coastal sediment.

e) The table *(fig. 1)* shows each sample contains organic material in some form. This refers to the samples taken from different parts of the layer and are not included in the table. We mentioned above, the samples with predominant manganese ore contain few pollens (or are free of pollens), but contain fraquently tissue fragments and amorphous organic rests.

SUMMARY

1) We examined by microscop 47 samples in all from manganese ore series of Urkut, 17 of them form a complete section.

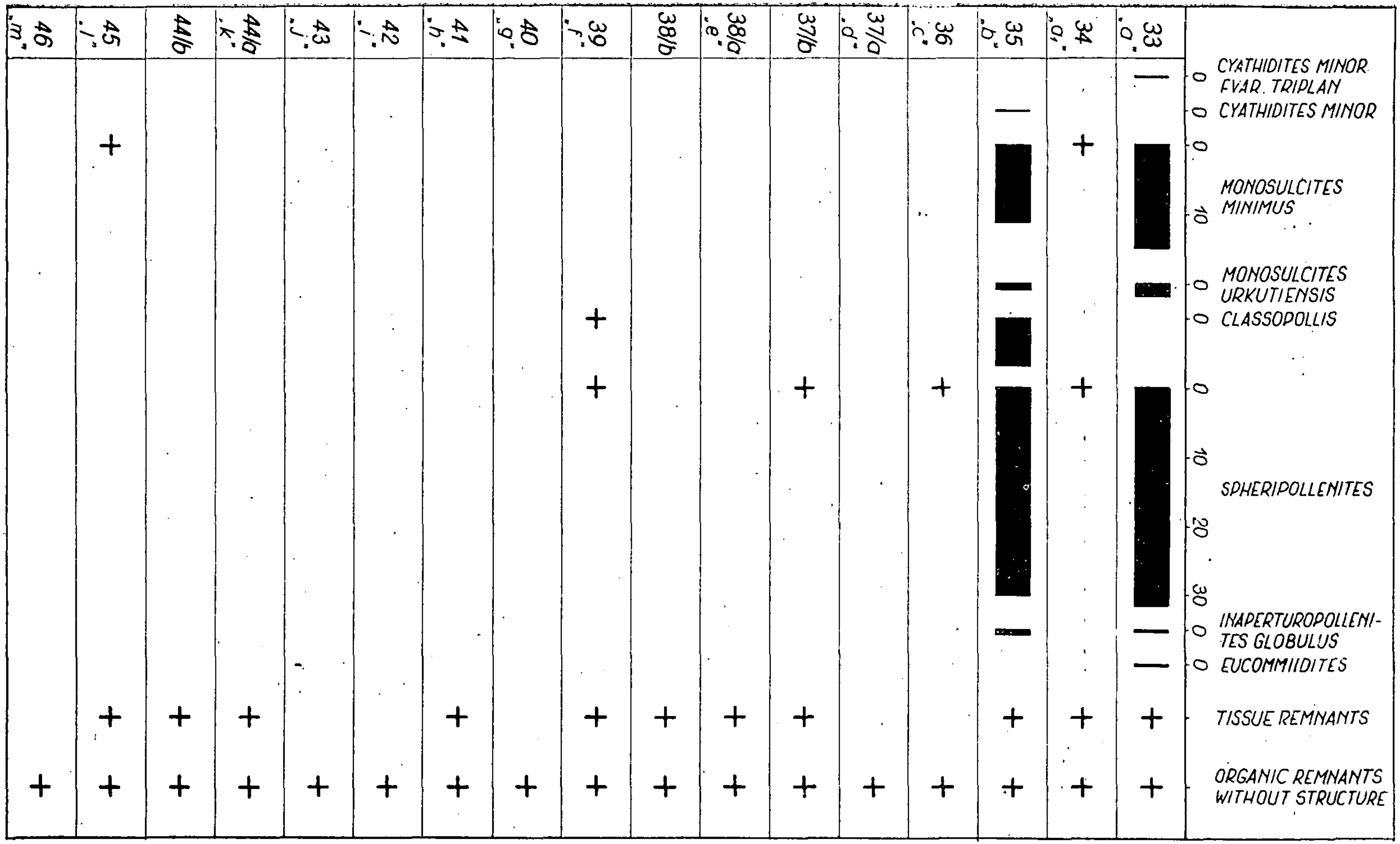
2) Each sample examined contains organic material in some form.

3) Rich in sporomorphs are only the samples *a* and *b*. We described 17 spores and 17 pollens from both samples, besides 2 new spores and 1 new pollen fsp.

4) The result of quantitative analysis of two samples rich in pollens indicates sea-shore or mixed salt-water sediment.

5) In consequence of the deficient palynologic data the period from Upper Lias to Lower Creta can be considered as geological age by reason of sporomorphous spectrum.

6) As far as possible we identified some sporomorphs from Liassic spectrum of Komló described by GÓCZÁN (1956).



33 „a"
34 „a,"
35 „b"
36 „c"
37/a „d"
37/b
38/a „e"
38/b
39 „f"
40 „g"
41 „h"
42 „i"
43 „j"
44/a „k"
44/b
45 „l"
46 „m"
CYATHIDITES MINOR FVAR. TRIPLAN
CYATHIDITES MINOR
MONOSULCITES MINIMUS
MONOSULCITES URKUTIENSIS
CLASSOPOLLIS
SPHERIPOLLENITES
INAPERTUROPOLLENI-TES GLOBULUS
EUCOMMIIDITES
TISSUE REMNANTS
ORGANIC REMNANTS WITHOUT STRUCTURE
0
10
20
30

Fig. 1.

Explanation of Plates.

Plate I.

1—3.	Cf. Algae
4—5.	Cf. Algae
6—8.	Cf. Algae
9.	Micrhystridium cf. arachnoides *Val.* 1955
10—11.	Micrhystridium recurvatum *Val.* 1955
12—13.	Artificial product
14—15.	Micrhystridium recurvatum *Val.* 1955
16.	Mycophyta spore
17.	Mycophyta spore
18.	Mycophyta conidium
19.	Cf. Algae, perhaps arteficial product
20, 22.	Mycophyta, hypha
21.	Mycophyta spore
23—25.	Inwashed Compositae pollen
26—27.	Caytonipollenites pallidus (Reissinger) Couper 1958

Plate II.

1—2.	Crassosphaera concinna Cookson and Manum 1960
3—4.	Crassosphaera concinna Cookson and Manum 1960
5—6.	Crassosphaera concinna Cookson and Manum 1960

Plate III.

1—2.	Leiotriletes pflugi n. fsp.
3—4.	Leiotriletes pflugi n. fsp. asp. triplanoid n. asp.
5—6.	Leiotriletes pflugi n. fsp. fvar. triplan n. fvar.
7—8.	Leiotriletes pflugi n. fsp. fvar. triplan. n. fvar.
9.	Leiotriletes pflugi n. fsp. asp. triplanoid n. asp.
10—11.	Cyathidites minor Couper 1953 asp. triplanoid n. asp.
12—13.	Leiotriletes pflugi n. fsp.
14—15.	Leiotriletes fsp.
16—18.	Toroisporis cf. transdanubicus n. fsp.
19.	Lycopodiumsporites clavatoides Couper 1958

Plate IV.

1—2.	Pteropsida, spora indeter., Type „A”
3—4.	Pteropsida, spora indeter., Type „A”
5—6.	Pterospida, spora indeter., Type „A”
7—8.	Pteropsida, spora indeter., Type „B”
9—10.	Cyathidites minor Couper 1953
11—12.	Toroisporis transdanubicus n. fsp.
13—14.	Pteropsida, spora indeter., Type „B”
15, 16, 18.	Pteropsida spora indeter., Type „B”
17, 19.	Punctatisporites rotundus Weyland and Greifeld 1953

Plate V.

1—4.	Perotrilites pseudoreticulatus Couper 1953
5—9. 14.	Trilites verrucatus Couper 1953 f. minor n. f.
10, 15.	Cyatheacidites fsp.
11—12.	Undulatisporites fsp.
13.	Punctatisporites fsp.
16—17.	Corrugatisporites arcuatus Weyland and Greifeld 1953
18—19.	Punctatisporites fsp.
20.	Cf. Pteridophyta spore.

Plate VI.

1—6. Polycingulatisporites circulus n. fgen. et fsp.
7—11. Lycopodiumsporites clavatoides COUPER 1958

Plate VII.

1—21. Monosulcites minimus COOKSON 1947 ex COUPER 1958
22—23. Monosulcites indet.
24—26. Monosulcites urkutiensis n. fsp. subfsp. hyalinoides n. subfsp.
27. Monosulcites urkutiensis n. fsp. subfsp. scabratus n. subfsp.
28—39. Spheripollenites subgranulatus COUPER 1958

Plate VIII.

1—15. Spheripollenites subgranulatus COUPER 1958
16, 23. Spheripollenites scabratus COOKSON 1958
17—18. Eucommiidites troedssonii ERDTMAN
19. Tricolporopollenites cingulum (R. POT.) TH. and PF. subsp. pusillus (R. POT.) TH. and PF.
20. Tricolporopollenites cingulum (R. POT.) TH. and PF. subsp. oviformis (R. POT.) TH. and PF.
21—22. Cf. Algae
26—29. Pollenites pseudohirsutus DOKT.-HREBNICKA ex PACLTOVÁ 1960
24, 30. Cf. Ranunculaceae
25, 31—37. Inaperturopollenites parvoglobulus WEYLAND and GREIFELD 1953
38, 39. Inaperturopollenites globulus WEYLAND and GREIFELD 1953

Plate IX.

1—25. Classopollis torosus (REISSINGER) COUPER

Plate X.

1, 4. Pteruchipollenites cf. thomasii COUPER 1958
2, 5. Parenchymatous tissue fragment
3. Tracheide fragment with bordered pits
6. Mycophyta conidium cuticle adhering
7—8. Monocolpopollenites fsp.
9. Epiderm (cuticle)

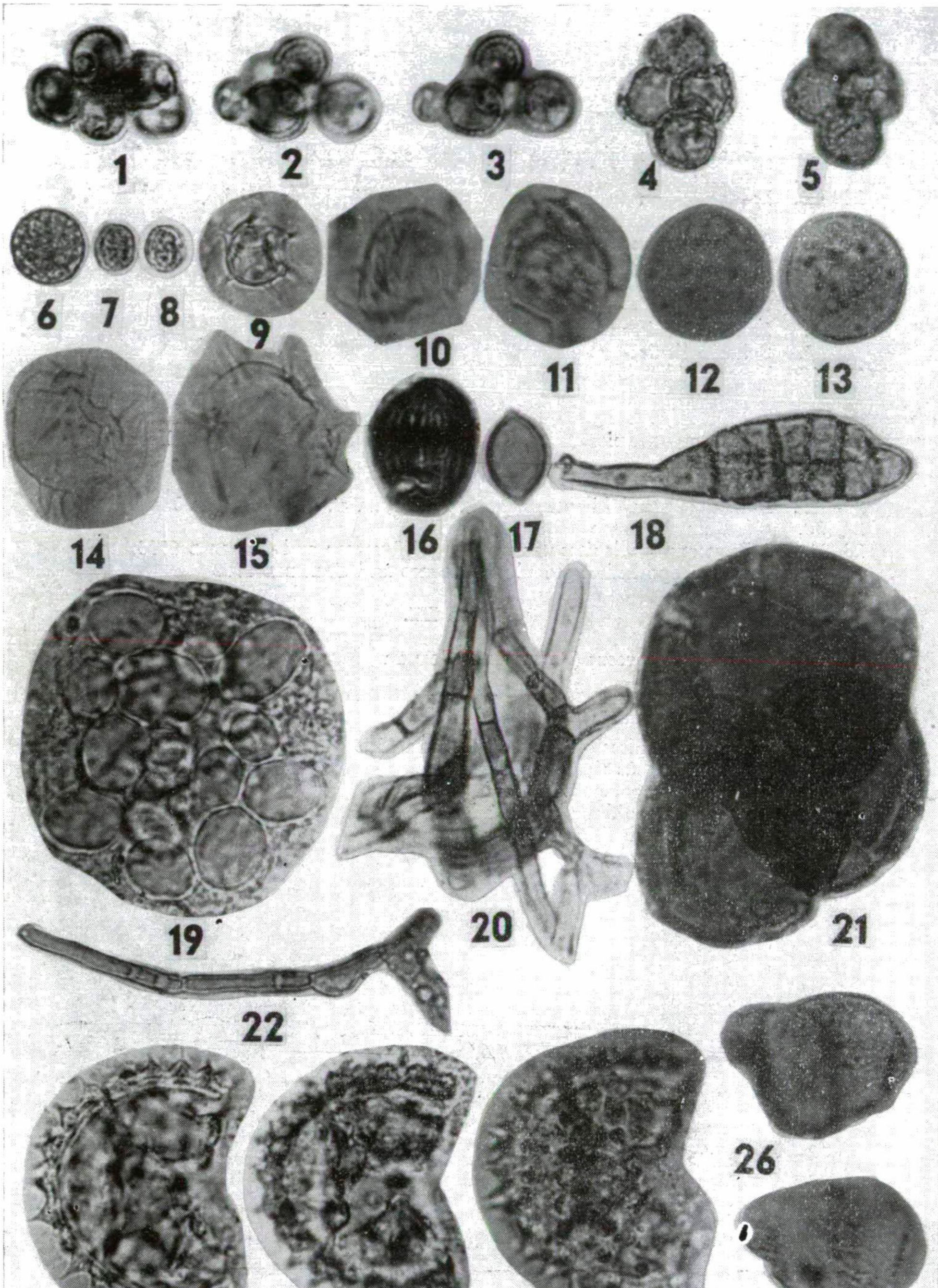


Plate I.

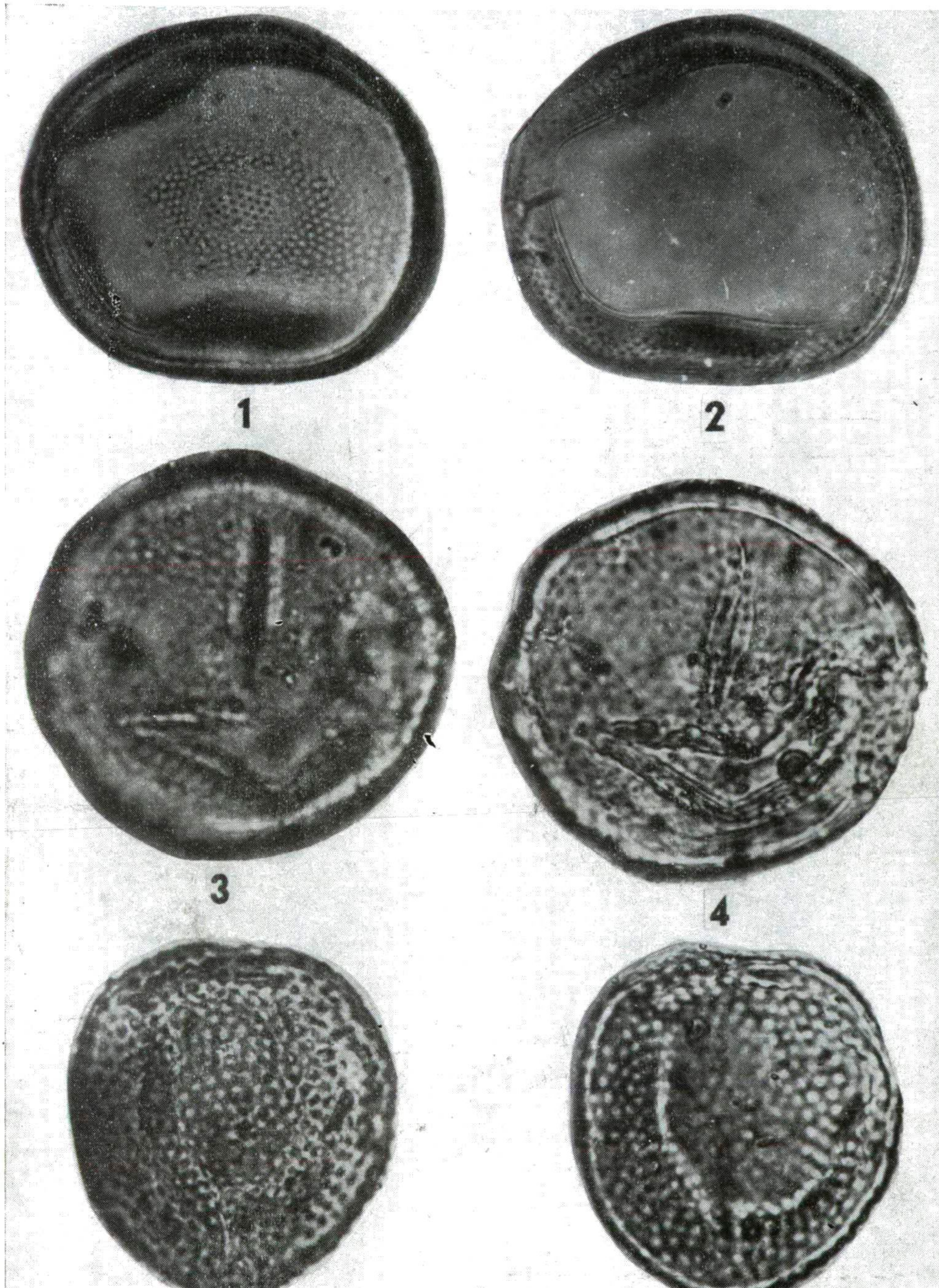


Plate II.

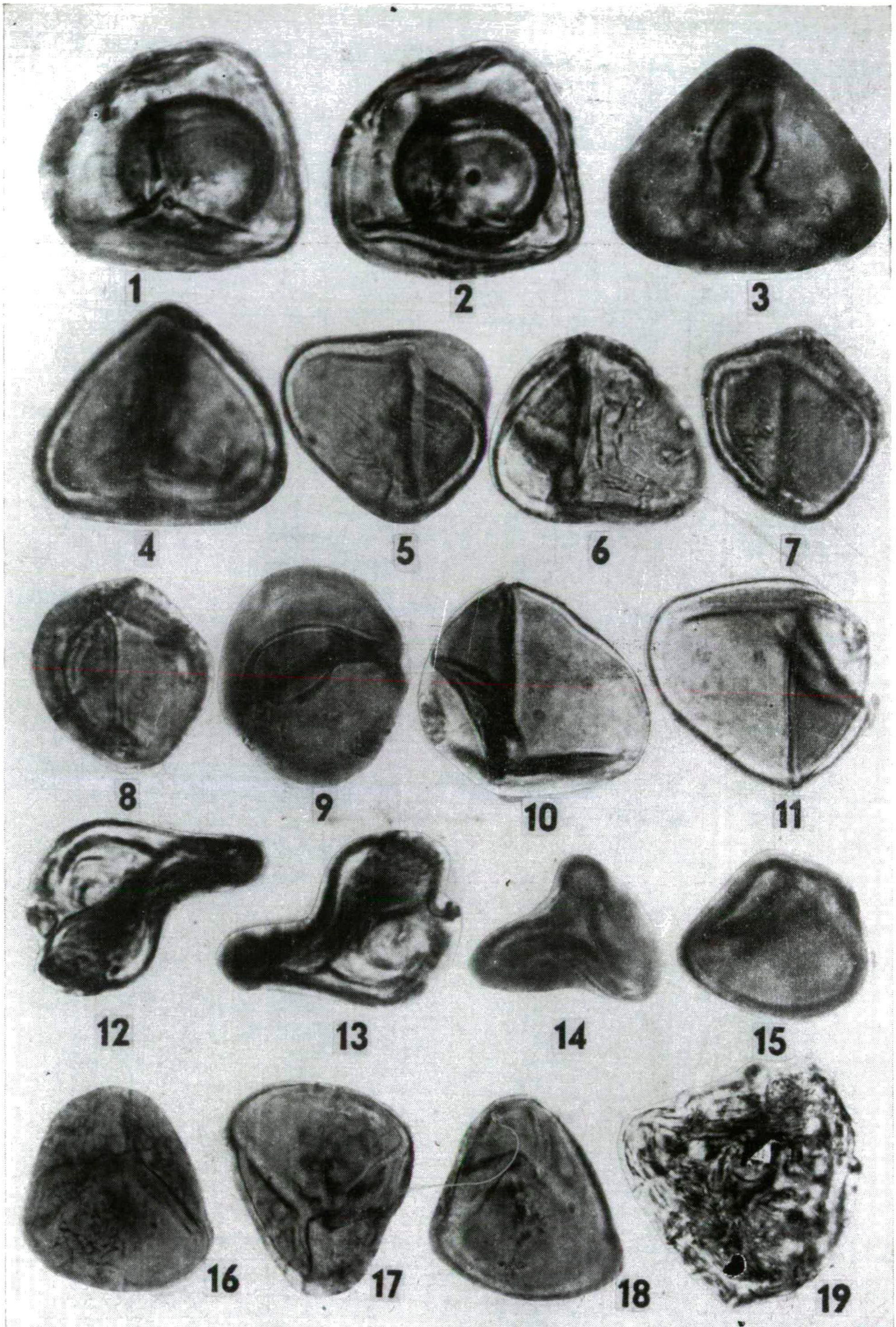


Plate III.

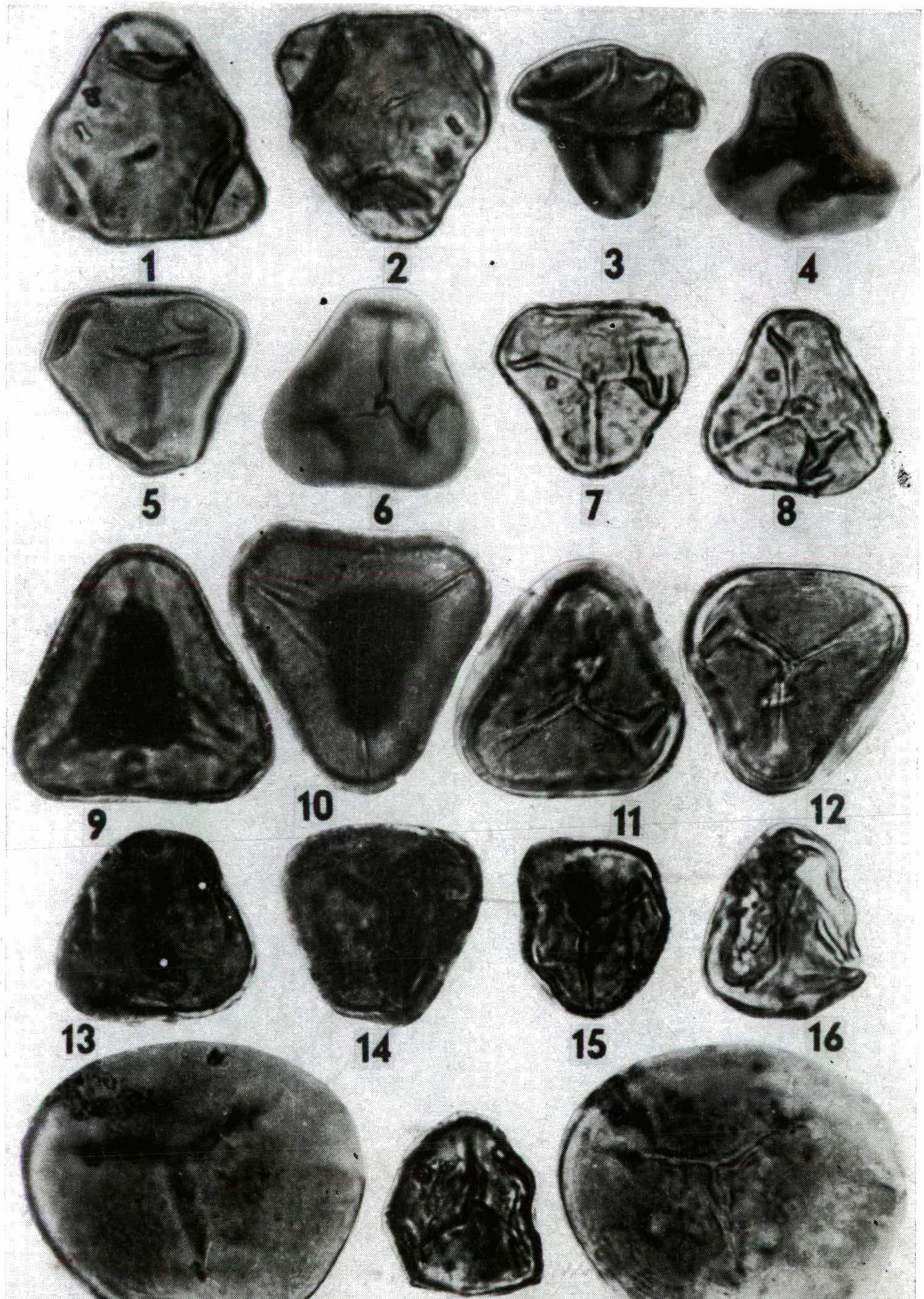


Plate IV.

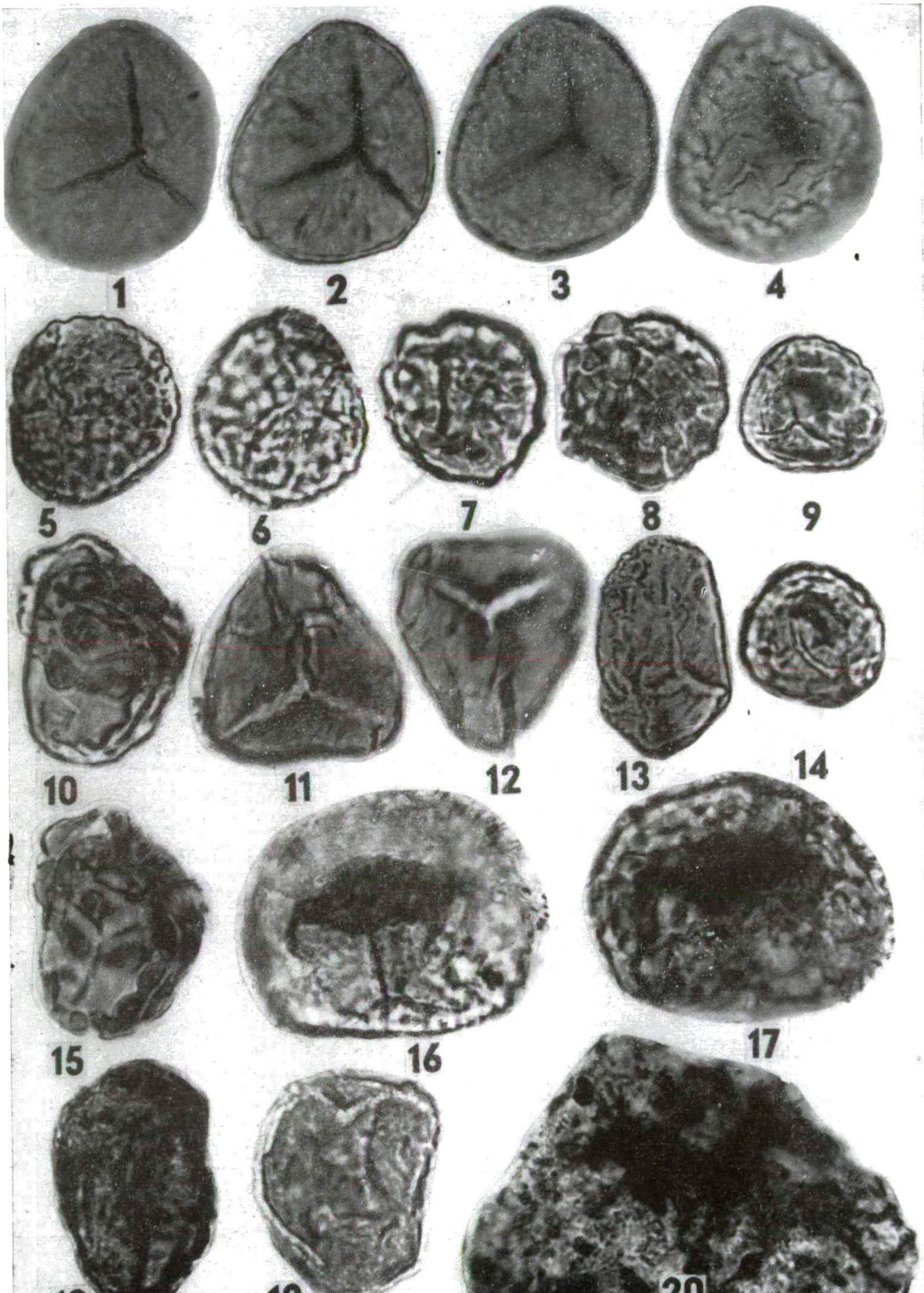


Plate V.

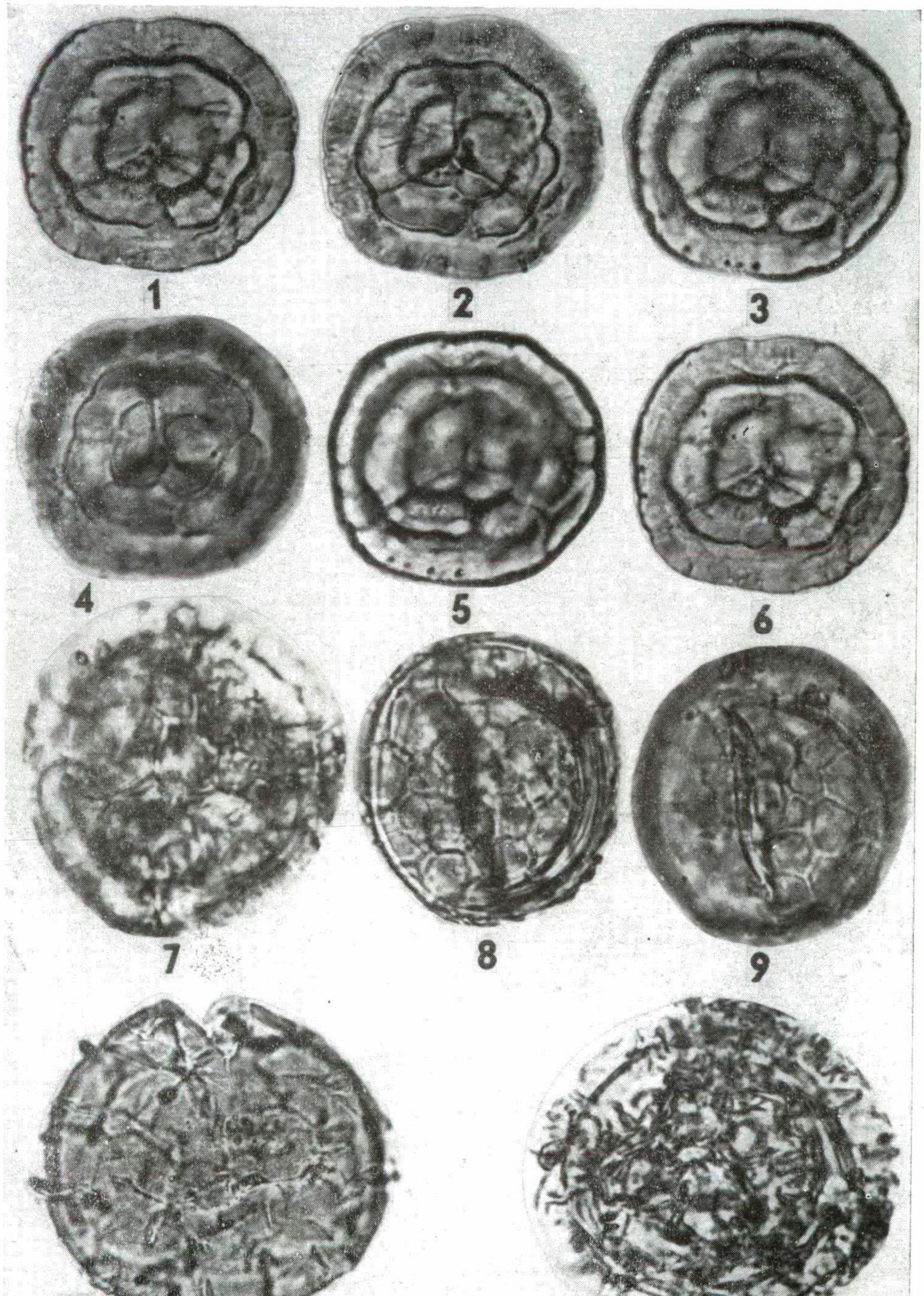


Plate VI.

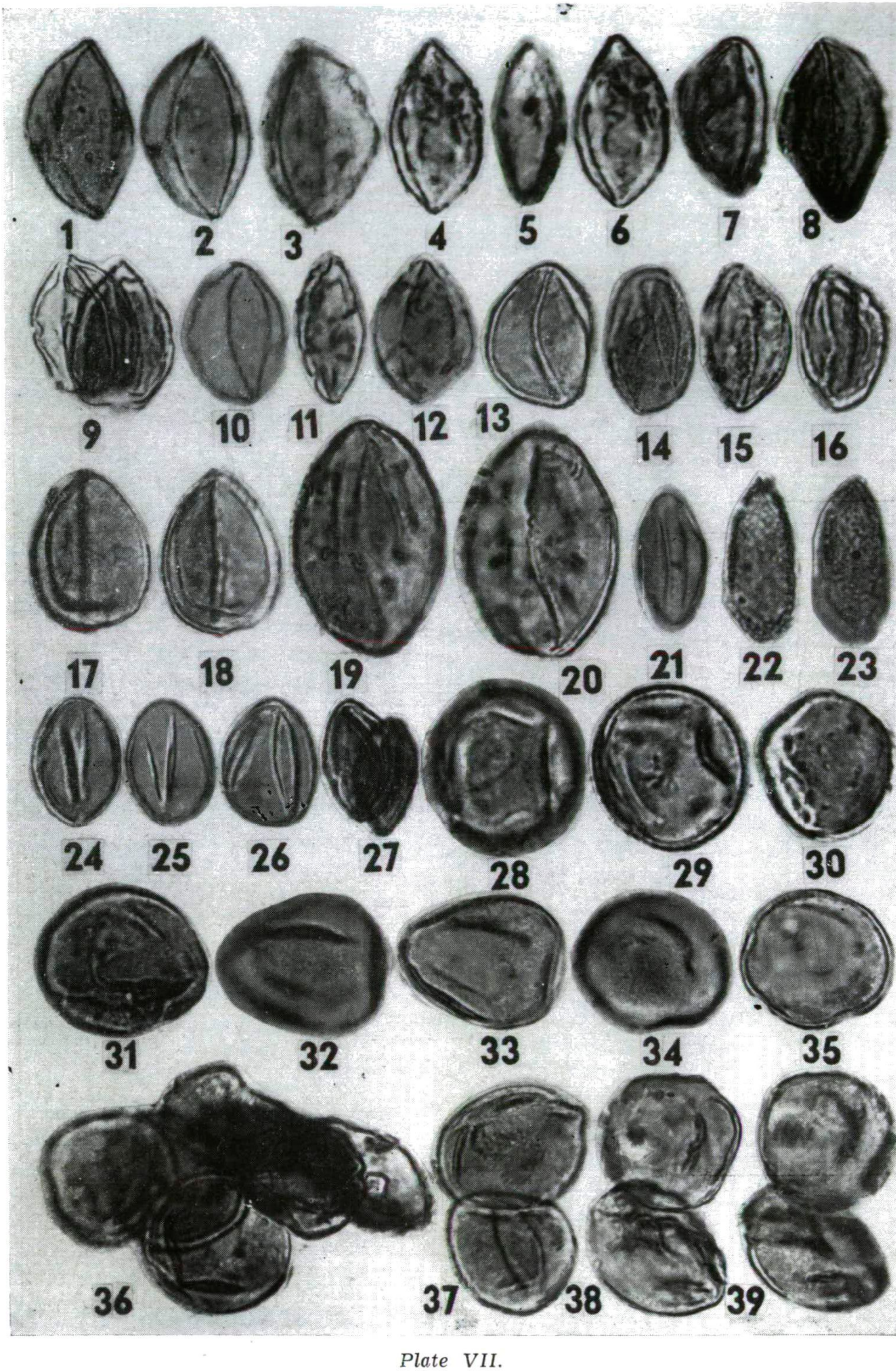

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Plate VII.

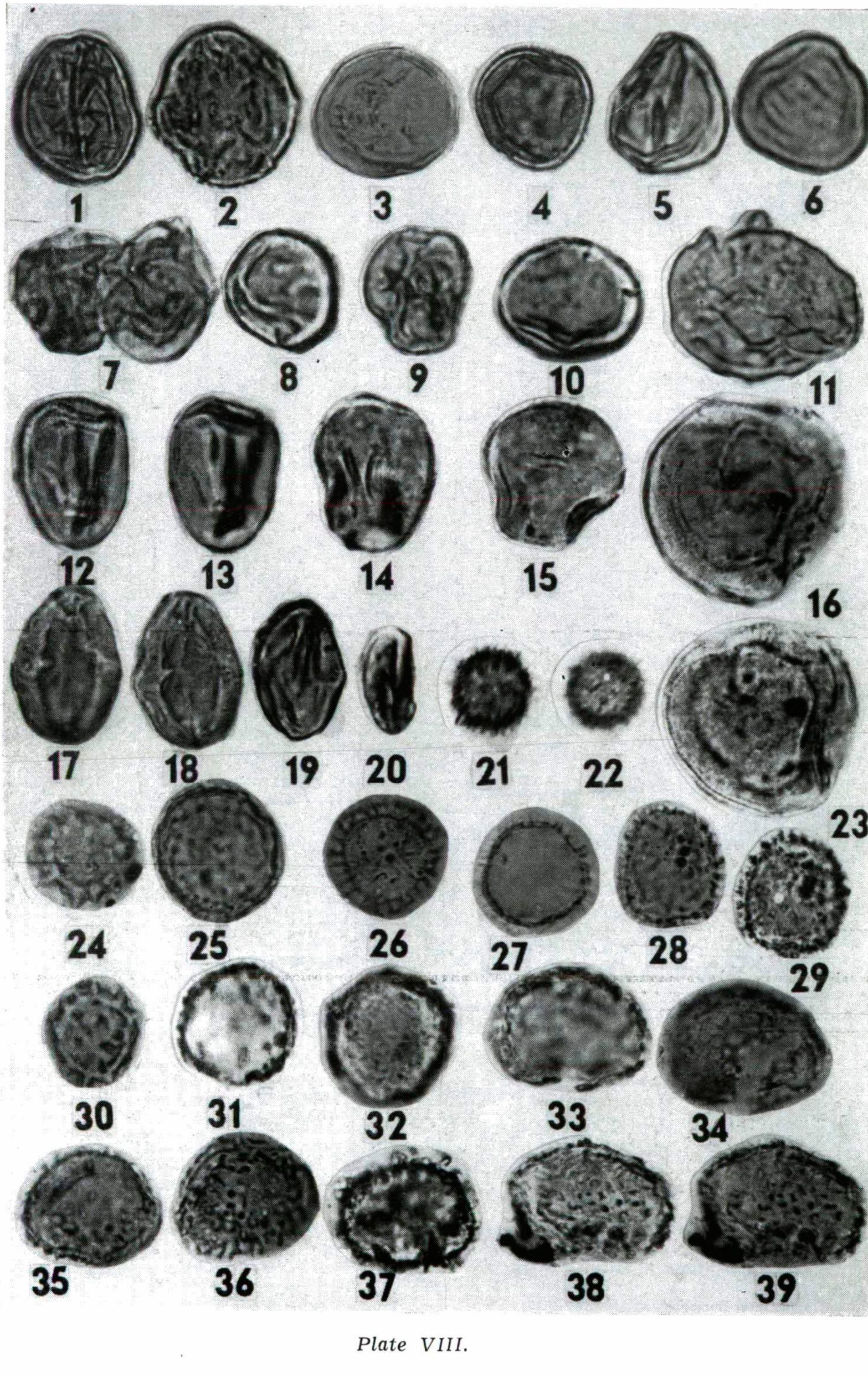
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Plate VIII.

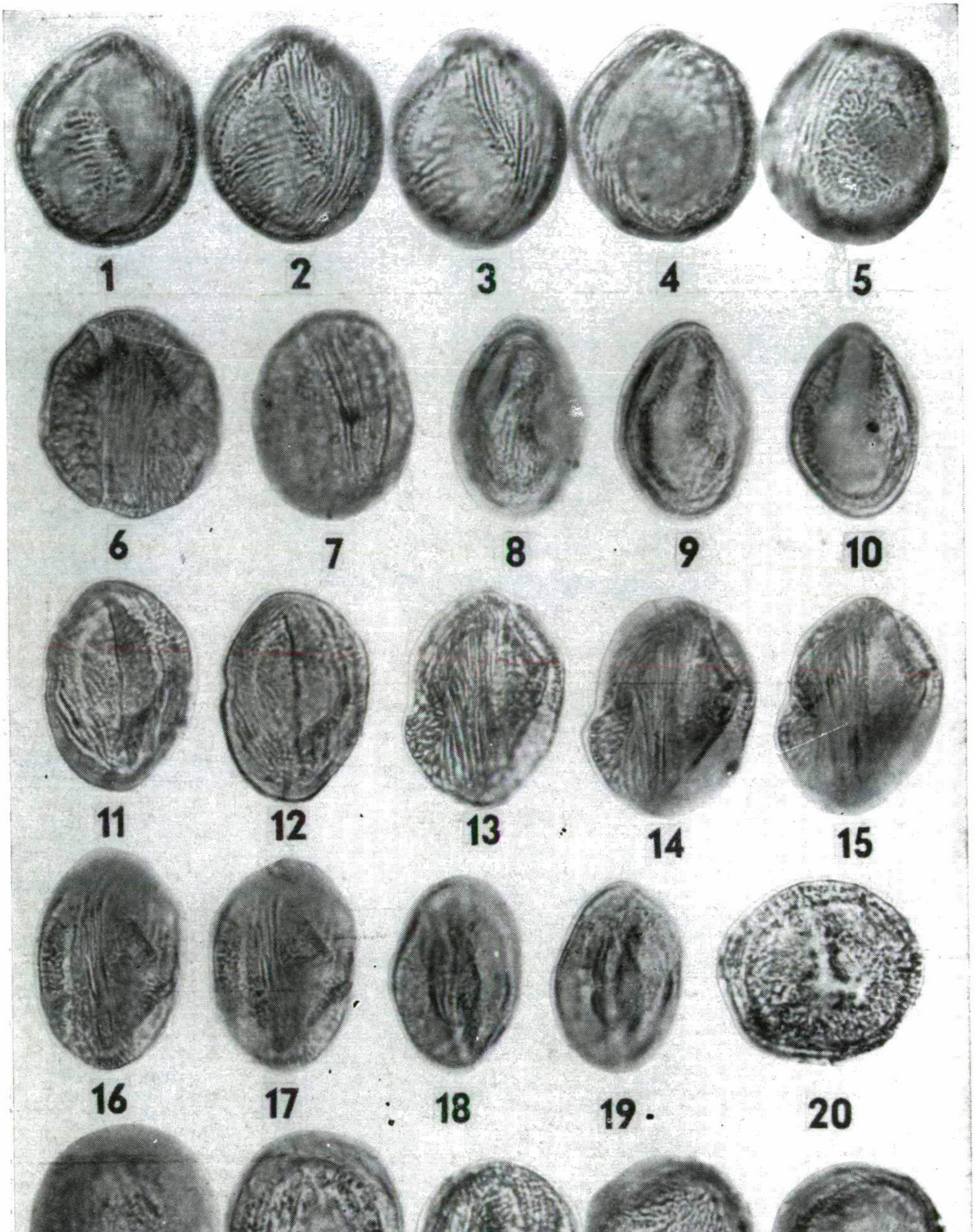

Plate IX.

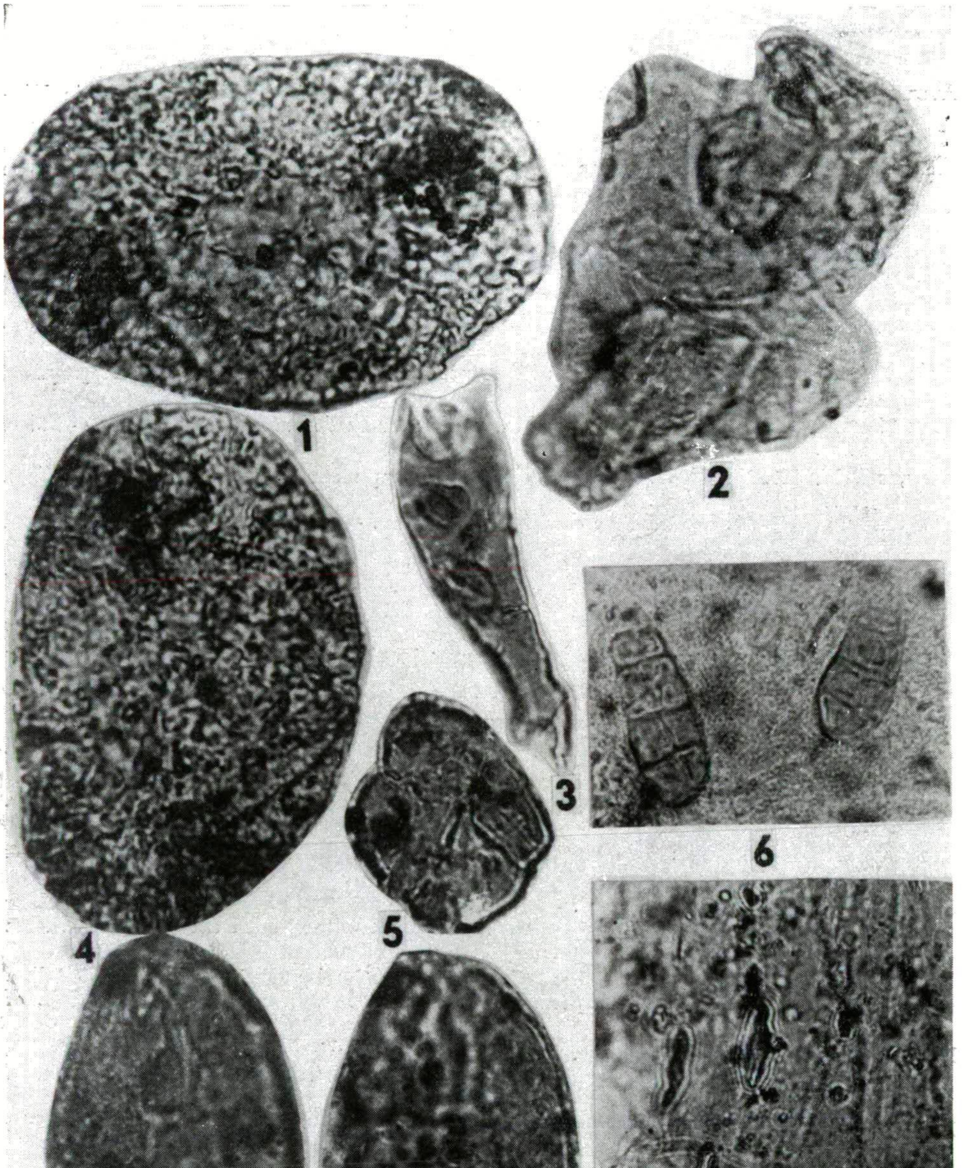

Plate X.

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THE OCCURRENCE OF STRIPED CALCITES CONTAINING MANGANESE IN GYÖNGYÖSOROSZI

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A. Vidacs in his work dealing with the structure and mineral association of the mine of Gyöngyösoroszi mentions white and black striped calcites which occur as 5th phase. Our institute has collected a considerable amount of these calcites. The pink, sometimes glowing red luminescence of the crystalline white calcite appearing in broad band prompted S. Koch to study more closely the stripe formation of calcites.

As can be seen on *Fig. 1* and *2* the white and black calcites vary to a great extent. In some places they separate rhythmically in stripes the white and black stripes alternate and in some other places they cross each other, frequently the black calcite stripe forms a circle and surrounds white calcite. However, even within the black stripe one, but often two, white vein appears too.

Examining the pieces under UV light the white calcites occurring in broad stripes show everywhere pink and in some places in small patches and sometimes in stripes a glowing red luminescence. The thin white veins occurring in the black stripes showed everywhere a white colour also under UV light. Under the black stripes a quite thin (about 3 mm) stripe appeared which showed a yellowish luminescence and was limited sharply from the calcite extending in its vicinity and showing a pinkish luminescence. Under ultraviolet light at the borders of the black and white tiny crystalline stripes this band could everywhere be seen whereas under white light it could only be detected in certain places.

Under white light and partly under ultraviolet one the striped calcites could be separated into the following bands:

1. White finely granulated dense calcite. The crystal granules grow as they proceed towards the black stripe *(Fig. 3)*. It shows a pink luminescence.

2. A black band forming — as can be seen on the photomicrographs — by an extremely finely distributed dark substance settling on the white calcite crystals and forming inclusion rows in fine stripes in them, exhibiting their parallel intergrowth. Macroscopically it consists of small crystals — rombohedrons — looking like a dense black stripe. The size of the black rombohedrons also increases as we proceed from the dense small granular white calcite towards the wider white calcite band consisting of larger crystals. This is well illustrated on *Fig. 4* and *5* prepared with the same magnification only No. 4 was photo-

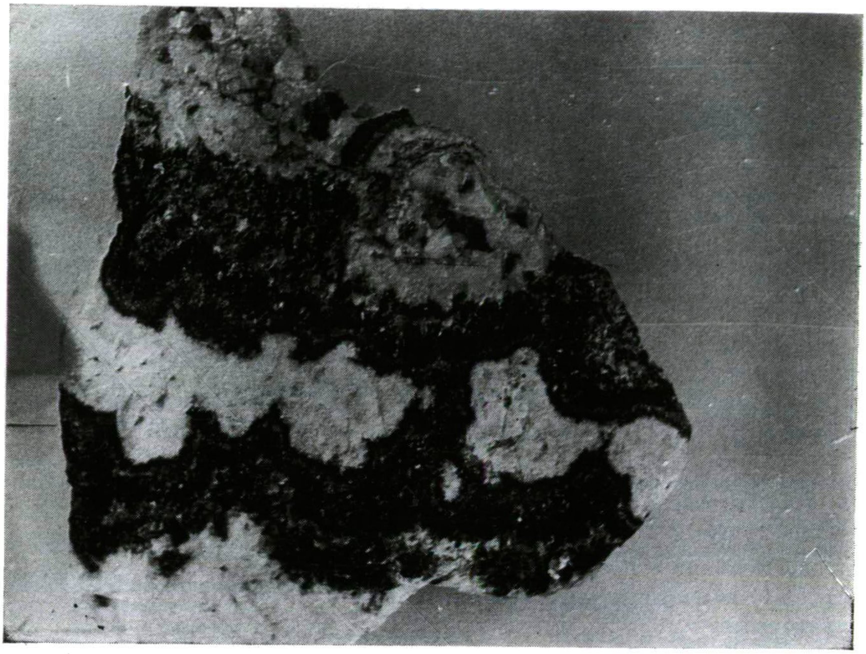

Fig. 1. White-black banded calcite. 1/2 natural size

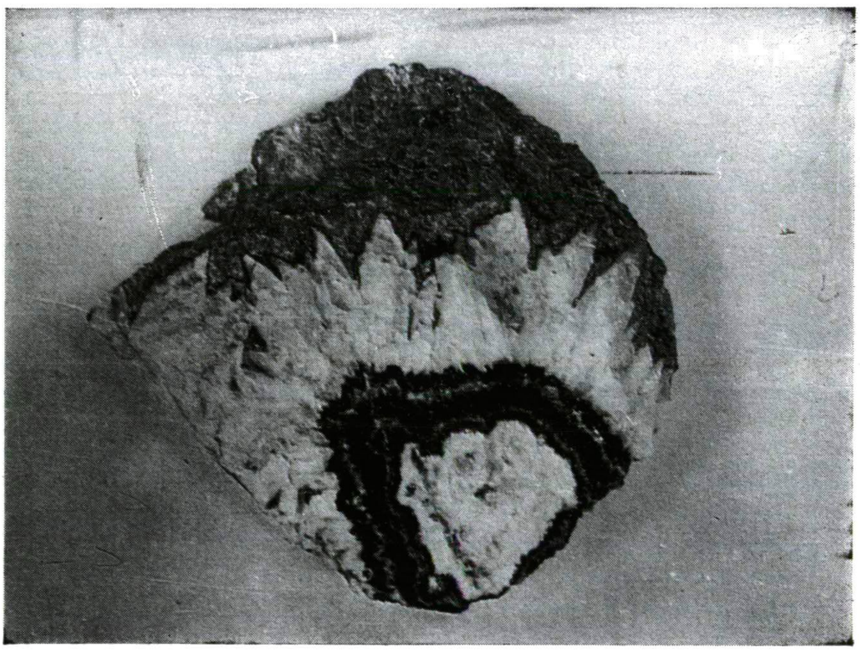

Fig. 2. Whit-black banded calcite. 1/2 natural size

graphed on the side of the dark band which is situated nearer to the small white calcite granules and No. 5 on that one situated nearer to the larger white calcite granules.

The inclusions are composed of dark-alternating sharp, and blurred-lines. Nowhere one can see a homegeneous dark band. *Fig. 6* shows the structure of a dark band under higher magnification.

The band rich in dark inclusions does not really adjoin the crystalline calcite along a sharp border line, but by crystal granules containing few inclusions *(Fig. 7.)*.

Already here along the dark rombohedrons in some places a thin pyrite vein appears, in some other places this vein limits only the white crystalline band (Fig. 2.).

3. In the black band a white calcite stripe without inclusions extends everywhere *(Fig. 8.)*. It does not show fluorescence.

4. On the black rombohedrons increasing in size a well developed stripe of white rombohedrons settles. On Fig. 9 it can be seen that the white band limited from the black calcite by a pyrite vein consists of considerably larger crystals than the calcite of band 1. On the Fig. 9. the twin lamellae and cleavage directions of the calcite crystals are well visible. This white band shows everywhere a pink fluorescence and this band contains the spots luminescing glowing red.

5. As 5th type may be mentioned that is composed of a thin band which can only be separated under ultraviolet light from the small granular calcite and probably only differs from it in its structure.

Although it does not belong to the white and black striped calcites we mention that these striped white and black calcites are associated with a reddish brownish calcite where the white calcite is bordered by pyrite. (Upper part on Fig. 2.).

The data of chemical analyses of the single bands are summarized in Table 1. The first part of the Table contains the analytical data, and the second one the mineral composition calculated on the basis of the analytical data. The denotations and numbers respectively used at the analysis correspond to the numeration of the above five bands. 1' etc. and 1" etc. means that similar bands were separated from a quite different sample.

From the analytical data the following conclusions can be drawn:

1. Samples 3, 3' and 3", thus the white vein extending in the black band proved to be everywhere ideally pure calcite, which did not contain manganese even in traces.

2. Of the selected substance only 1 and 1" samples contained SiO_2 as insoluble residue which was composed of the thin quartz veins occurring in some places in the small granular dense white calcite.

3. The pyrite vein associated with the bands points to the fact that FeO and $FeCO_3$ occurs everywhere except in the white vein extending in the black band. The reddish brown colour of the calcite appearing above the pyrite vein limiting the white broad band is caused by the greater amount of iron content of this calcite as compared to the other ones.

4. With the exception of calcite No. 3 which is ideally pure, manganese can be found in every band, the white calcites contain $MnCO_3$ the black ones probably MnO.

Fig. 3. ×20

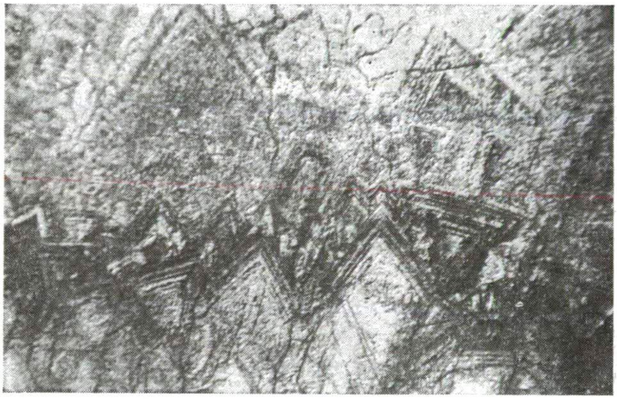

Fig. 4. ×20

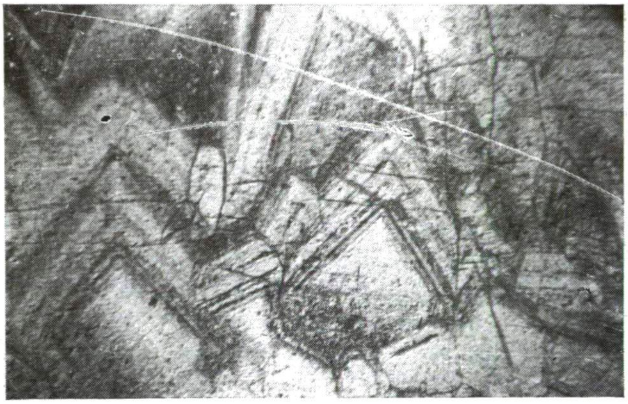

Fig. 5. ×20

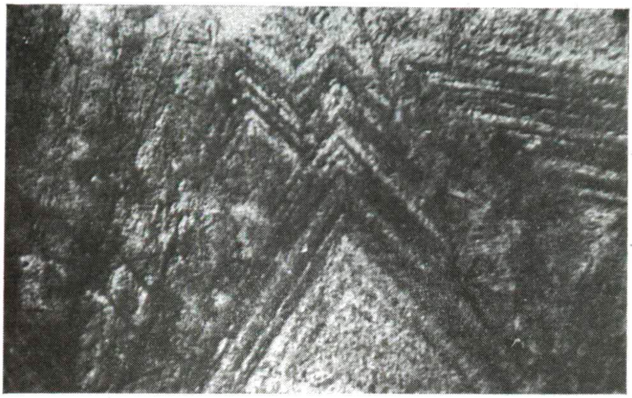

Fig. 6. ×70

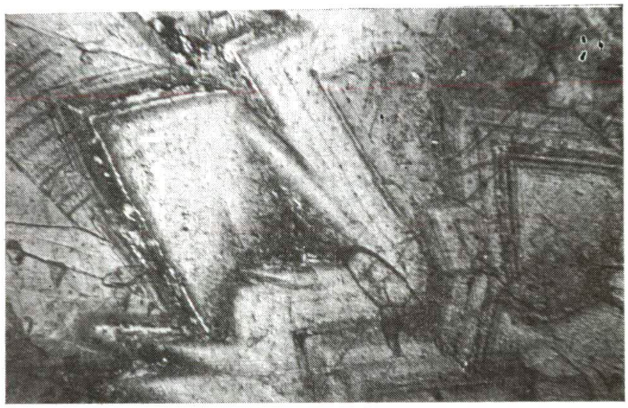

Fig. 7. ×20

Fig. 8. ×12

Table 1.

Number of the types	CaO	MgO	FeO	MnO	CO_2	SiO_2	$CaCO_3$	$FeCO_3$	$MnCO_3$
1	52,58	—	1,71	1,39	42,79	1,50	93,84	2,38	2.25
2	54,23	—	1,25	1,36	43,20	—	96,77	1,91	
3	56,07	—	—	—	43,98	—	100,05	—	—
4	54,18	—	1.12	0,89	43,74	—	96,68	1,80	1,45
5	55,02	—	—	1,03	43,82	—	98,20	—	1.67
1'	53,05	—	1,80	1,50	43,64	traces	94,65	2,91	2,43
2'	54,00	—	1,59	1.03	43,37	—	96,40	2,57	—
3'	56,08	—	—	—	43,88	—	99,96	—	—
4'	54,80	—	traces	1,29	43,82	—	97,91	—	2,09
5'	55,19	—	—	1,00	43,81	—	98,38	—	1,62
1''	52,72	—	1,00	1,42	41,86	3,02	93,20	1,61	2.30
2''	54,32	—	1,02	1,45	43.22	—	96,91	1,64	—
3''	56,00	—	—	—	43,94	—	99,94	—	—
4''	54,13	—	1,09	0,97	43,73	—	96,59	1,76	1,57
5''	53,88	—	1,02	1,38	43,80	—	96,13	1,64	2,23
reddish brown	52,68	—	3,12	0,89	43,17	—	94,00	4,35	1,45
reddish luminescent	56,09	—	—	traces	43,92	—	100,01	—	—

5. The substance prepared under ultraviolet light from the part luminescenting glowing red proved on the basis of the analysis to be pure calcite with manganese traces. It is known from the literature that the presence of manganese ions in minimal amounts may induce the strong red luminescence of the substance, it is therefore probable that the strong luminescence of the striped calcites from Gyöngyösoroszi is also due to this fact.

Thus according to the analysis the white-black band of the striped calcites is caused by the manganese occurring in various forms in the different stripes, i. e. the dark colour of the band which seems to be black is due to the manganese content of the extremely fine inclusions present possibly as MnO in the calcite.

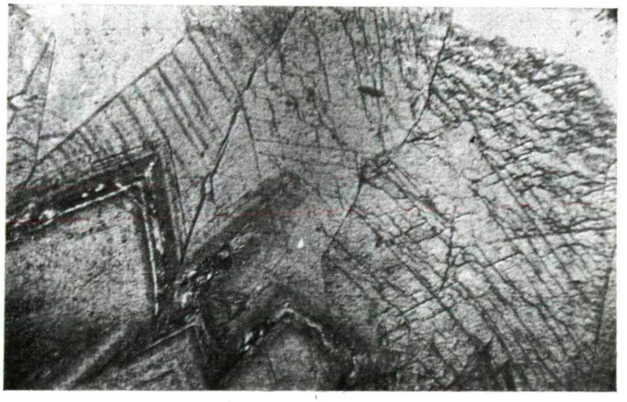

Fig. 9. ×20

We prepared the DTA curves of the single bands too, however, under the experimental conditions a peak corresponding to either $MnCO_3$ or MnO did not appear. Presumably the apparatus was not sensitive enough to record the relatively small quantity.

Unfortunately the X-ray pattern did not either show lines corresponding to MnO, however, this is not only due to the small quantity, but also to the fact that most probably this MnO which appears in extremely finely distributed stripes does not separate in crystals. Thus conclusions could only be drawn on the basis of the analytical data so that the analyses were performed very carefully, the components in the parallels were determined by various methods.

When we began to investigate striped calcites and prepared the first analyses about 15 per cent $MnCO_3$ was found in the white calcite. Then the question arose whether mangano-calcite or kutnahorite is involved, however, in the course of the systematic examinations (determinations of the manganese content were still carried out from numerous other places which are not illustrated on the Table) we did not succeed in finding calcite containing such large amounts of manganese.

Examinations are in progress to determine why and under what conditions $MnCO_3$ separate beside each other or subsequently. Presumably the pH, the redox-potential and last but not least, or just in accordance with the above, the CO_2 content and the CO_2 atmosphere over the crystallizing solution play a role.

Experiments were carried out according to which in the course of an hour in a CO_2 current heated to 600° and at 300—400° C in 4 hours, artificial $MnCO_3$ transformed in MnO. It may be that at lower temperature this change may also take place in the course of a longer period and possibly the occurrence of calcites containing $MnCO_3$ and MnO in alternating stripes showed also be attributed to the CO_2 atmosphere, or just to its absence, at the separation, this question requires, however, further investigation.

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ZEOLITE OCCURRENCE IN THE MÁTRA MOUNTAIN

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SUMMARY

In the cavities of agglomerates of opaline and chloritous andesite tuffs appearing above the schlier formation in the Middle Mátra chabazite and natrolite occur. The oldest mineral in the cavities is chlorite, chabazite and natrolite are younger. Considering that the rocks of the Mátra contain little alkalies, the appearance of natrolite may be accounted for by transvaporisation. The shapes of the zeolites show very little variation. In the opaline part the size of the crystal needles reaches one cm, in the andezite tuffs it is 1—2 mm. Chabazite is always smaller. The succession of the separation may also be characterized by the fact that the sequence of the compound potentials decreases.

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In the Mátra Mountain at the eastern part of the Gallya group the Vércverés (694 m) and the Bagolykő (689 m) are steeply limited towards the North whilst south-westwards they form a gently sloping mountain side. The material of both the Vércverés and the Bagolykő consists of pyroxene andezite containing more hypersthene and less augite. To the North of the Bagolykő on an area thickly covered with debris partly weathered there is a small hill in the direction of Parádsasvár, the „Vadak orma" (520 m) which is remarkable from the point of view of zeolite occurrences.

In a southern direction of Parádsasvár along the „Vadak orma" a helvetian schlier was opened up which according to the examinations of Gy. Varga contains sporadically silicified remnants of tree truncs. Underneath there is thick bedded sandstone which disintegrates towards the top into lamellar pieces frequently 3—5 cm in size. This contains dark coloured finely granular clay embeddings. Sometimes it looks like an eroded suface. Above it sandstone occurs disintegrating always lamellarly. The clayey character of the dark coloured settlements is also illustrated by the fact that their DTA diagrams show the presence of montmorillonite *(Fig. 1/a.)*.

According to the data of the literature rhyolite tuff and andesite tuffs are superimposed on the sandstone. It is, however, interesting that on the north-western side of the „Vadak orma" between the sandstone and the andesite tuffs there is a liver brown in some places blackish brown, opaline separation, which may be followed in fragments along the level during a short distance.

This siliceous rock is ensnared by thin white fissures *(Fig. 2.)*. If along these fissures the rocks are separated in the fissures of the thinner cavities chalcedony and natrolite appearing in radial fibers may be found. In the fissures the appearance of fine needles as well as the phenomenon that the ends of the needles are mostly occher yellow may be well observed. The colouration is due to impurities settled on the top which are always well visible under the microscope even under lower magnification. (Fig. 3.).

On the sandstone on the „Vadak orma" agglomeratous andesite tuffs may be found which differ greatly from the similar formations of the neighbourhood. The andesite tuffs vary in colour, generally they are greenish and mostly cemented out of andesite lapilli. Usually the andesite lapilli do not contain coloured minerals. The feldspars are intact, the older minerals porphyrous separated are altered the most. The cementing material is in the first place chlorite, furthermore quartz and limonite which in some places colours the rocks intensively, it may be clay too. In this case the rocks show a hydro-character, montmorillonite appears *(Fig. 1/b.)* The matrix of the lapilli shows generally a pilotaxitic structure. Sometimes lapilli with a dacitic character may also be found in the rocks. The colour of the lapilli varies. It depends upon the matrix (glassy or less glassy), the one to which the colour is due and the impurities. The matrix of the more glassy ones is usually densely scattered with magnetite granules and these are also darker. In the matrix of the lapilli magnetite occurs in the form of crystal skelets. The octahedral shape is always well visible on the skelets. Larger independent magnetite granules occur rarely. The feldspars are mostly very altered, they show a clay mineralization. Under crossed nicols sometimes only the outlines indicate the original size and shape of the feldspar, however, under parallel nicols it may always be well detected *(Fig. 4.)*. Their size is at the most 1,2 mm. They sometimes contain smaller

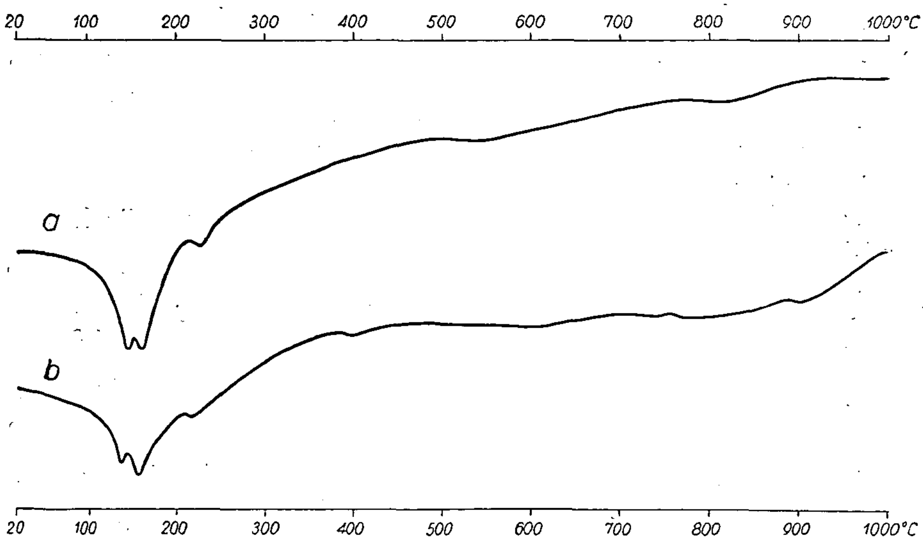

Fig. 1. a) DTA curve of clayey sandstone.
b) DTA curve of chloritous andesite tuff.

cavities filled up by chlorite. Also originally the rocks only contained few coloured minerals. This may be attributed to the chlorite patches some of which developed in a pseudomorphous manner.

The small irregular cavities of the rocks 1—4 mm in size, mostly filled up by chlorite, are interesting. Sometimes the cavities compose one quarter of the rocks. On the walls of the cavities a sort of chlorite with a weak fibrous character showing a dark green colour appears in several very thin layers superimposed on each other. They always run parallel with the wall of the cavity thus they follow the shape of the cavity. Then a small granular light green sort of chlorite succeeds. The smaller cavities are completely filled up by these two sorts of chlorite, but sometimes only by the granular one *(Fig. 5.)*. In larger cavities the chlorite also contains zeolite.

There may be two kinds of zeolite. In some cavities, mainly in the larger ones, both occur, in the smaller ones only the one. If only one sort of zeolite may be found this is always chabazite and it frequently fills out the cavities completely. The cubic like sections of the small crystals are always well visible under the microscope. The natrolite is always the younger, its fine needles are embedded in the chabazite and are always situated in the middle of the cavities. The straight extinction of the radial fibrous natrolite needles and that of the smaller crystals is always unambiguous. It is striking that although carbon acid springs which are still functioning occur frequently in the environment and calcite formation also often occurs here, yet no calcite can be found *(Fig. 6, 7.)*. The natrolite shows both in the cavities of the chloritous andesite tuff agglomerations and in the jasperous part a very simple structure, the shape of the crystals does not vary to a great extent. The columns are usually termined by bipyramids. On the larger crystals the fibrous structure may be well observed *(Fig. 8.)*.

Thus in the Mátra Mountain two kinds of zeolites are known. In the one the matrix contains in some places zeolite which has also been pointed out earlier by B. MAURITZ and the other form is when it fills up smaller cavities as described above. The zeolite occurring in the ore veins of Gyöngyösoroszi is hydrothermal, its genesis is, however, different. Not taking the occurrence of Gyöngyösoroszi into account also in this case the zeolite formed if also not simultaneously but in two generations, which has also been established by. E. SZÁDECKY-KARDOSS in the case of the zeolites of the basalts in the vicinity of the Balaton.

The occurrence of the Mátra like that of the zeolites of the basalts of Transdanubia can be found in rocks settled on clayey sandstone containing a greater amount of moisture. On the action of the volcanic rocks settled on the sedimentary rocks water steam develops in them, which migrates upwards to the magmatic rocks. The volatiles decompose the feldspar of the magmatic rock partly iniciating the zeolite formation, but the zeolites of the matrix may also form in this way. This, however, does not play an essential role in the Mountain of the Mátra. The second phase is here also represented by the zeolites overgrown on the cavities which occur here in few species.

The latter mostly appear in a chlorite environment which is always the oldest mineral in the cavity fillings. If we taken into account that the temperature of chlorite formation is 100—300° C and according to NIGGLI-KÖNIGSBERGER that of the zeolites 70—90° C the formation temperature will

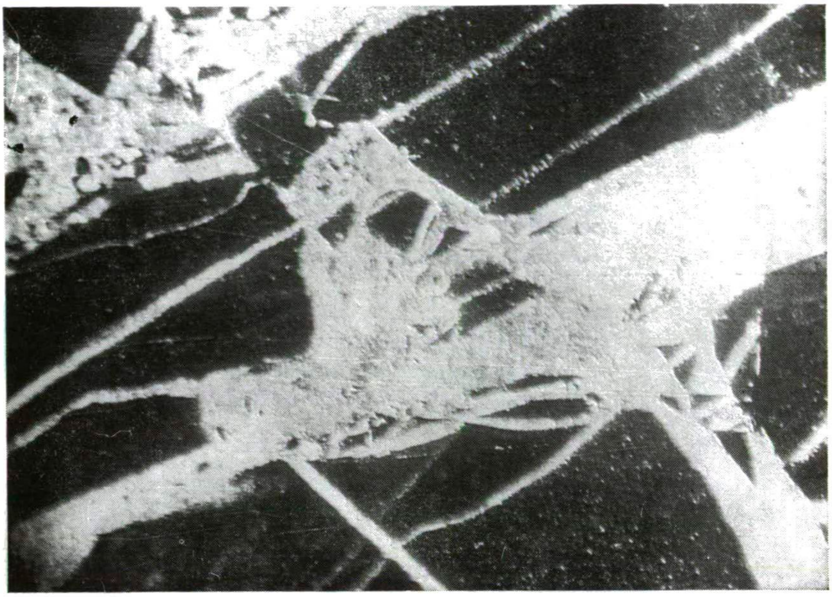

Fig. 2. Zeolitic veinlets in siliceous rock. Thin section, plain light, ×30.

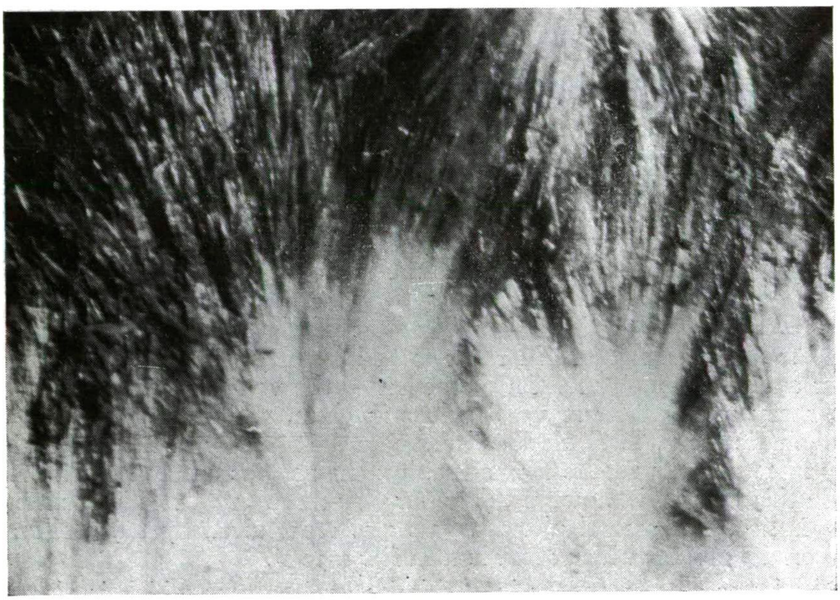

Fig. 3. Crystal aggregate of natrolite in a cavity of siliceous rock. Thin section, plain light, ×25.

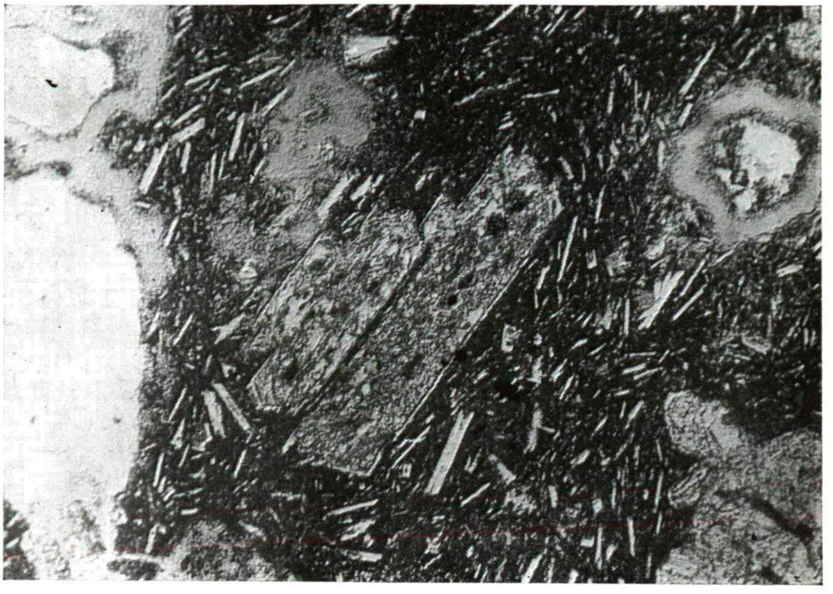

Fig. 4. Altered feldspars in andesite tuff. Thin section, plain light, ×80.

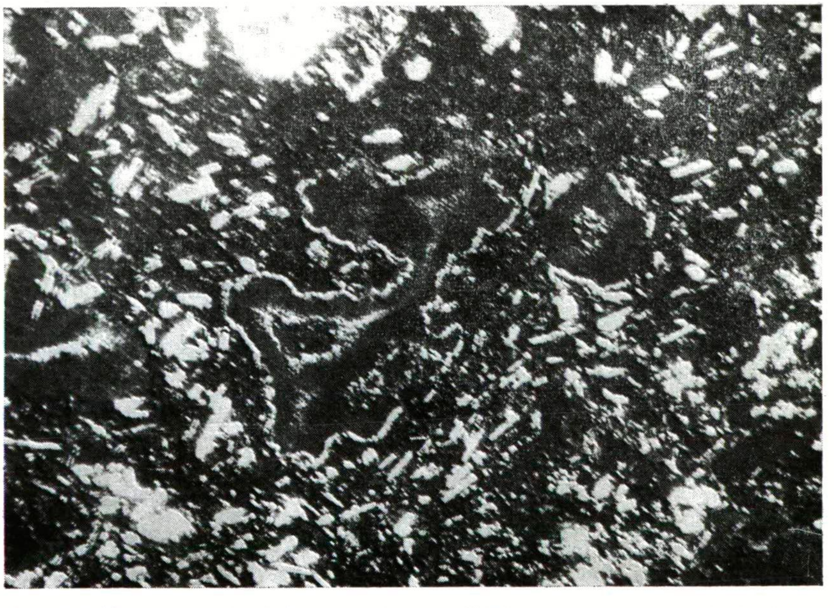

Fig. 5. Chloritous cavity-filling in andesite tuff. Thin section, crossed nicols, ×80.

not vary considerably in this case either, thus they formed at a relatively low temperature. Considering that there is transvaporization between schlier and the magmatite settled on it there is undoubtedly also an interaction between the country rock and the magma. That this interaction really exists is proved by the fact that on the action of the volatiles the feldspars decomposed to a great extent and were replaced by secondary clay minerals so that often only a narrow intact border shows the original state.

The appearance of natrolite in the Mátra Mountain is unusual. All the more because the rocks of the Mátra in the first place the andesites, contain very little alkalies. This is also suggested by the fact that at the rock norms-calculations there always remains an excess of aluminum oxide after the formation of the feldspars. Thus the formation of natrolite can only be accounted for by Na^+ migration.

It is well known that Na is easily soluble and knowing the solubility conditions of SiO_2 according to which with the increase of the pH value a larger amount of SiO_2 dissolves, the SiO_2 migration seems also natural. At lower temperatures the SiO_2 becomes still more mobile. If therefore there was not a larger amount of Na^+ in solution, there was enough silicic acid available for the formation of hyrosilicates (zeolites), partly on the basis of this fact and partly through the silicic acid released due to the weathering of the feldspars. The above holds good, if also to a smaller extent, for the Ca^{2+} ion thus finally what kind of minerals form in the cavities will be determined by the ratio of the ions taking part in the migration. The migrating elements migrate partly as ions and partly as complex anions.

That schlier and the sedimentary rocks beneath it contained and contain Na^+ and that its migration must be taken into account is proved by the fact that the spring at Parádsasvár — near to the occurrence — breaking up to the surface from the sandstone of Oligocene age contains a considerable amount of Na^+. Expressed in THAN values this quantity amount to nearly 56 per cent. Simultaneously the amount of Ca^{2+} is about 28 per cent, whereas that of Mg^{2+}: is 16—17 per cent.

E. SZÁDECZKY-KARDOSS examining the sequence of formation of the zeolites contained in the basalts in the vicinity of the Balaton as well as the formation-temperature of the zeolites contained in the fissures of the crystalline schist of the Alps establishes that this succession is partly determined by geo-energetic facts in turn partly determined through the properties of the lattice structure. Hence, first the cubic, then the lamellated and finally the fibrous zeolites form. Taking the ionic potential values into consideration the minerals occurring in this neighbourhood may be ranged in the following sequence:

Mineral	Compound potential
Pennine $(MgAl_3)(OH)_2AlSi_3O_{10}$	2,92
Chabasite $(CaNa_2)(Al_2Si_4O_{10}) \cdot 6H_2O$	0,91
Natrolite $Na_2(Al_2Si_3O_{10}) \cdot 2\,H_2O$	0,83

In the case of the zeolites the number of the water molecules was not taken into account. In view of the low potential values this value decreases for the cubic zeolites to a somewhat greater extent and for the fibrous zeolites somewhat less. This is, however, partly compensated by the different — mainly

Fig. 6. Natrolite and chabasite in cavity filled out by chlorite. Thin section, crossed nicols, ×80.

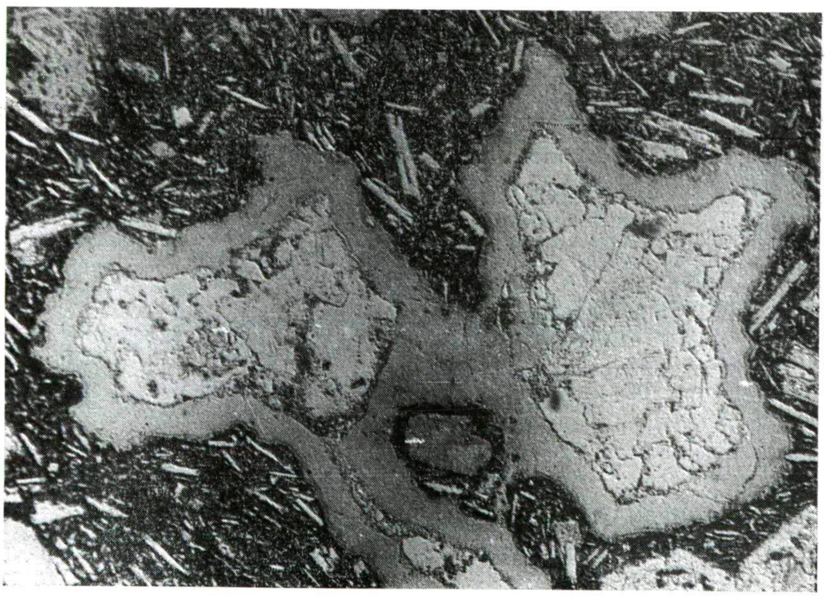

Fig. 7. Zeolites in chlorite-filled cavity. Thin section, plain light, ×80.

Si-Al — possibilities of substitution. Finally the succession of formation established on the basis of the data collected by other observations, is also supported by the fact that the compound potential values decrease.

The synthetic experiments prove that the formation temperature is low, besides the temperature values the composition of the solution plays an important part too. Hence for example, from a system containing Na_2O, Al_2O_3, SiO_2 and H_2O at 80–180° C natrolite, at higher temperatures till 430° C analcite and at still higher temperatures nepheline forms.

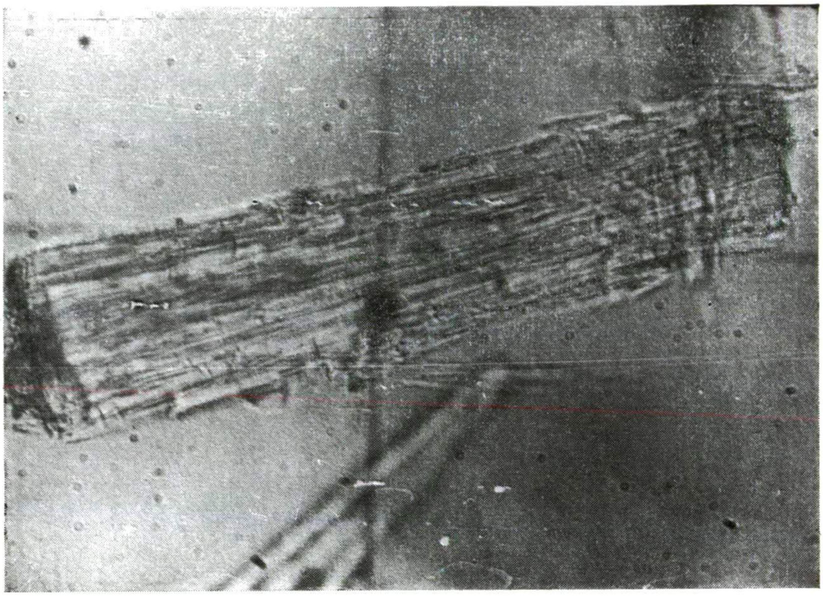

Fig. 8. Fibrous natrolite crystal. Thin section, plain light, ×500.

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ON THE LAWS GOVERNING SEDIMENTATION FROM EOLIAN SUSPENSIONS

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1. INTRODUCTION

Research history shows that the first to study the general physical and geological laws governing sedimentation from eolian suspensions was UDDEN (21). In his paper published at the end of the last century, this author treated the grain size distribution of dust and detritus caught up by air currents in a mostly descriptive, compilative manner. His work was considerably extended in the direction of pragmatism and experimentation by KÖLBL (8, 9), who determined the fall velocity of particles in air, as well as the interdependence of fall velocity and the grain size of the deposited sediment. However, the work of these two scientists did not ripen into a comprehensive interpretation that would have granted a full insight into the topic.

Our detailed studies in sedimentary petrography made it a necessity to inquire into every one of the interwoven phenomena playing a part in deposition, for in the lack of considerations of this kind none of the basic problems of the process can be correctly interpreted, not even the role of fall velocity.

In a paper published in 1956 (16), the problems of the velocity of settling, movement and sorting of the falling particles were already discussed by the present author in a number of respects. However, in the mentioned study no complete synthesis was arrived at, either, because the study of the interrelations of eolian and fluviatile deposition was missed; neither was the process of internal sorting due to transportation at high altitudes cleared. However, it was just by these considerations that the general laws of deposition of suspended dust could be elucidated. The present paper has the aim of summarizing the results achieved so far by the present author, and published in his earlier papers, concerning the process of deposition from eolian suspensions, and of subsuming these results under a uniform point of view.

The most generally studied property of mechanical sediments is their grain size distribution, a feature which stands in a close relation with a number of their physical properties and is one of the most important indicators of their ways of formation. Concerning the grain size distribution of e. g. the finer fluviatile deposits, we have generally accepted notions of long standing of which excellent use can be made when the genesis of some sediment of this type is to be determined. The grain size distribution of the loess of eolian genesis is another well-known characteristic, the interpretation of which is, however, still lacking. Even the problems of the stratigraphic role and of the genesis of loess depend on the correct recognition of its mechanism of deposition. In the opinion of some, loess could not possibly have in this country under the climatical conditions of some phases of the Pleistocene, namely simultaneously with wind-blown sand, whereas others assert that loess is a heteropic facies of wind-blown sand and that both come from a nearby source. The decision of this problem, too, must be based on research into the laws governing the deposition of the sediments in question: we must study the interrelation of the grain size distributions of eolian dust and wind-blown sand, we must establish numerical relations between the grain size distributions of the rolled and suspended fractions blown out of some accumulation of detritus.

As an introduction, let us consider the fall velocity and the floating properties of the sedimentary particles; then we shall pass on to the study of the facies relations of the grain assemblages, that is, of the sediments and trace them throughout the process of sedimentation.

2. THE RELATIONS GOVERNING FALL VELOCITY IN STAGNANT AIR.

According to investigations by Kölbl (8, 9) the fall velocity in air of grains of different size varies as the diameter of the grains down to a diameter of 0,05 mm. However, grains smaller than that drop considerably slower. This means that, to keep up suspended particles under 0,05 mm, a disproportionately slower air motion is sufficient than for particles above this size; that is, the particles of the dust fraction are fairly liable to remain in suspension for long periods. The table below lists the diameters and fall velocities of the grains, partly as determined by newly performed experiments.

Diameter mm	*fall velocity cm/sec*
0,01	2,8
0,02	5,5
0,05	16
0,06	50
0,1	167
0,2	250
2,0	500

The data concerning the grains above 0,06 mm diameter were taken from Kölbl's work whereas those for the smaller grains were experimentally determined by the present author. The experiments were performed in the following way.

Grain size fractions of 0,005—0,01, 0,01—0,02 and 0,02—0,05 mm diameter respectively were separated by the *Atterberg* method of washing. After drying, the particles were sedimented in air in a tube of 1 metre length ending below in a glass cylinder. The grains were introduced by smearing a very small amount of the preparate onto a sheet of paper which was subsequently placed over the upper end of the tube, with its smeared face down. The particles were propelled into the tube by a single pat on the paper. The settling velocity was then measured through the glass cylinder, under appropriate illumination.

The results were checked by a different method. The sample was introduced into an open paper tube of 1 m length and after the elapse of 3, 4, 5, 10 and 20 minutes, respectively, a sheet of black paper was slid under the bottom end of the tube. The size of the particles settling onto the black paper was measured under the microscope. *(Fig. 1.)*.

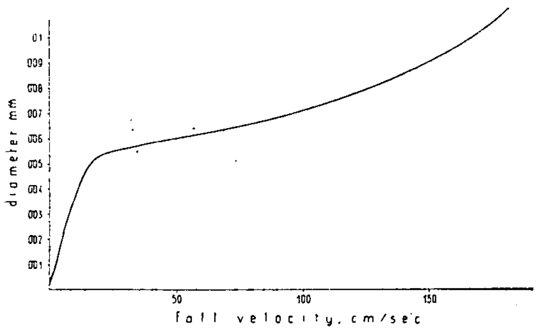


Fig. 1.

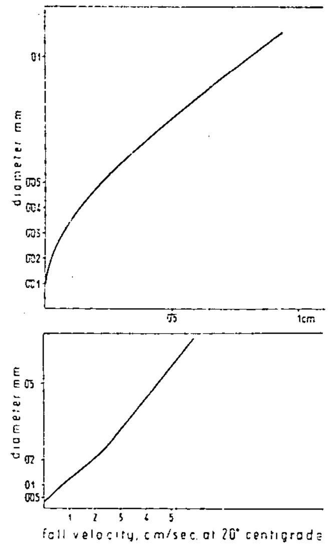
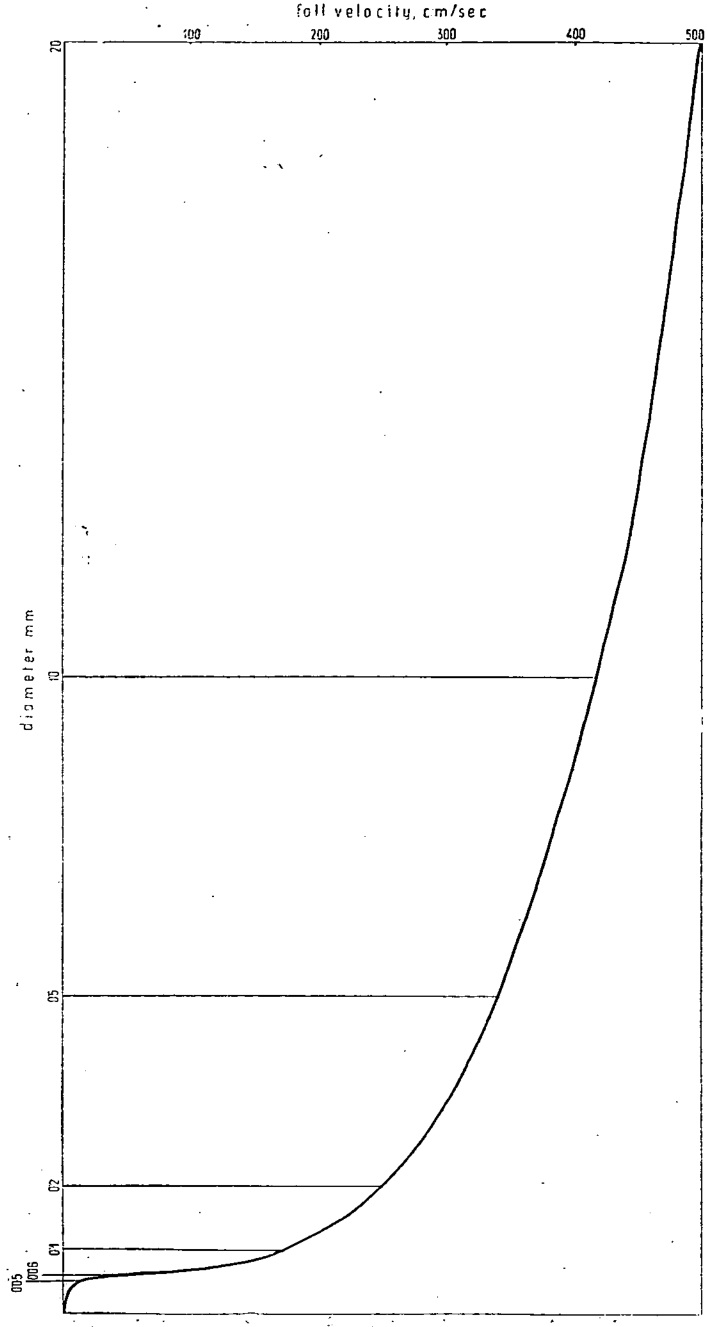


Fig. 2.

Let us note that a fall velocity graph of similar trend is obtained if Kölbl's data only are plotted. Extrapolating his curve beyond the point of 0,06 mm grain size to the zero point, we have a graph that does not differ in principle from the above one. Hence, Kölbl was certainly in a position to establish the principal difference between settling in water and in air, without any further measurements; he did not mention any result of this nature, though. On the contrary, he reached the conclusion that the sharp break occurring in air at the grain size of 0,05 mm is analogous to that occurring at 0,02 mm in water. However, the inspection of Stokes's settling-velocity table and of the digram constructed therefrom for water clearly shows that the mentioned section of the graph is almost straight and exhibits no sudden increase of the floating ability. *(Fig. 2.)*.

Fig. 3. shows the settling velocity in air of particles from o to 2 mm.

The argument becomes even more convincing if the settling velocity of the grains of a given dimension is compared to that of the grains smaller by one hundredth of a millimetre. Thus for instance the settling velocity of the grains of 0,05 mm diameter is 16 cm/sec, whereas that of the grains of 0,06 mm size is 50 cm/sec. $50/16=3\cdot1$, or, in words, the floating ability of the grains of 0,05 mm size is 3,1 times as great as that grains of 0,06 mm size. For the grain size of 0,06 mm this ratio is 2 (that is, the floating ability of the grains of 0,06 mm size is twice that of the grains of 0,07 mm size); for the grain size



fall velocity, cm/sec
100
200
300
400
500
diameter mm
20
10
05
02
01
006
005

Fig. 3.

of 0,04 mm it is about 1,4. The results are shown by *Fig. 4.* For the sake of comparison, we have presented also in this case the appropriate ratios for grains settling in water. *(Fig. 5.)*

In air, the peak at 0,05 mm divides the grains into two fractions of particularly good and particularly poor floating ability, respectively. *(Fig. 4.)*.

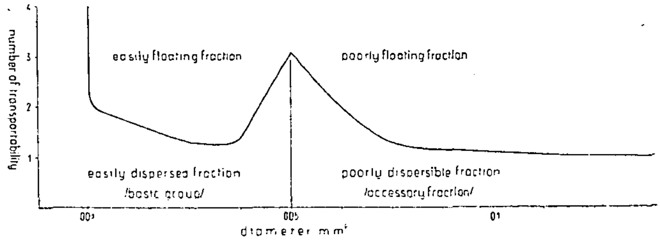


Fig. 4.

The grains below this limit drop at a rate of *at most* 16 centimetres, those above at a rate of *at least* 50 centimetres per second. The figure shows further that around 0,05 mm even a slinght change of diameter results in a considerable change of the fall velocity.

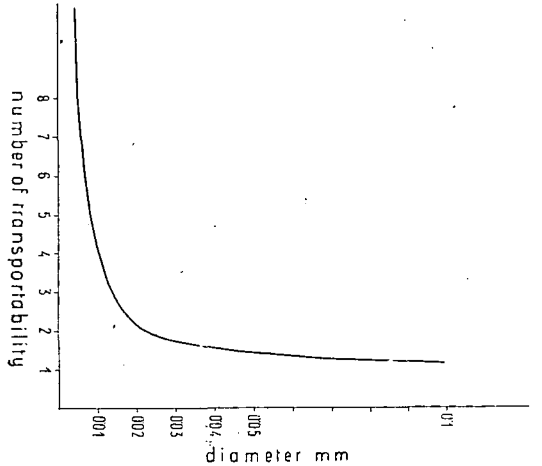


Fig. 5.

The behaviour of the two groups is characteristic also as regards the dispersion effected in the course of transport and settling. The grains of fair floating ability are widely dispersed and conversely. In the light of this recognition it shall be possible to trace the evolution of the grain size distribution of both the suspended fraction and the fraction travelling close to the ground. As regards numerical values, we shall return to this point later on.

This peculiar feature of the settling-velocity diagram clearly reflects a property of the drag of the medium. The obvious reason for the sudden increase of the fall velocity in air at the grain size of about 0,05 mm is that the drag of the medium decreases at a disproportionate rate with the increase of the diameter, that is, of the mass of the particle. *(Fig. 6.)*. A change of diameter from 0,05 to 0,06 mm is equivalent to an increase of mass by round 70 percent, whereas the settling velocity and consequently the drag of the medium increase in the same interval by 210 percent!

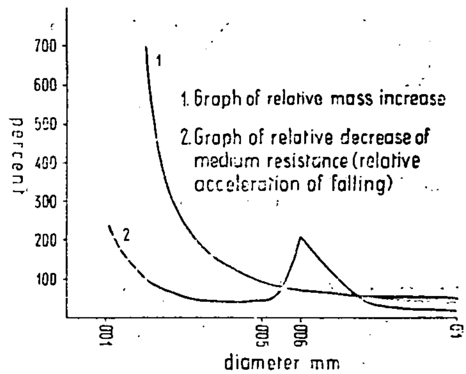


Fig. 6.

Concerning the rest of the grain size groups we have the following relations:

Change of diameter,				Increase of mass, percent	Increase of settling velocity or decrease of drag of drag of medium, percent
from	0,01	to	0,02 mm	700	
„	0,02	„	0,03	237	90
„	0,03	„	0,04	137	51
„	0,04	„	0,05	95	39
„	0,05	„	0,06	70	39
„	0,06	„	0,07	60	210
„	0,07	„	0,08	50	96
„	0,08	„	0,09	43	29
„	0,09	„	0,1	37	18

If the density of the grains is increased instead of their diameter, a similar drag diagram results. In essence, both the increase of the grain diameter and of the density result in an increase of the downward-moving force, the force of gravity acting upon the grain. It follows hence that, should the gravity acceleration on the Earth surface increase to twice its present value, the critical grain size would be shifted towards a particle mass half as great, that is, towards the diameter of 0,04 mm — always provided that the density of the air would remain the same. In the above case the upper grain size limit of ideally sorted loess would be 0,04 mm instead of the actual 0,05 mm. An increase of the gravity force to ten times the present value would entail a shift of the critical limit to 0,023 mm, a decrease of the same order a shift to 0,11 mm. Consequently, a gravity force ten times greater would have resulted — assuming that the dust was blown out of an aggregate containing relatively few removable, unbound grains of 0,01 to 0,02 mm diameter and that the air density remained unchanged — in the formation of considerably less and considerably better-sorted loess than was the case in the Pleistocene, since the fraction of 0,02 to 0,05 mm diameter, constituting the bulk of Pleistocene loess, would have entered the wind-blown sand fraction, owing to the poor floating ability of the grains. On the other hand, a gravity force less by ten times would have entailed the formation of much more and much worse-sorted loess. This circumstance will have to be taken into account when considering the eolian dust deposits formed in the ancient gravity field of the Earth which was possibly of a different strength. *(Fig. 11.).* It is to be emphasized that in our computations we have left out of consideration the change of volume and taken the change of mass only. *Fig. 6.* is thus, as a matter of fact, a diagram of mass or diameter *vs.* drag and thus not wholly coincident with the curve of density *vs.* drag.

The point at which the fall velocity takes a sudden increase is to be considered a characteristic physical parameter of the medium in which falling occurs.

3. THE RELATIONS GOVERNING THE VELOCITY OF PARTICLE MOTION IN MOVING AIR.

If in the course of settling the air moves upward at the same speed at which the particles would fall in stagnant air, the particles will evidently keep on floating at constant altitude. Consequently, a particle floating at constant altitude must be moving at its characteristic fall velocity with respect to the gas molecules. The particle is kept at constant altitude by the drag of the gas molecules moving upwards; the latter impart to the particle their kinetic energy in the course of innumerable collisions and thus neutralize the downward pull of the gravity force.

It is obvious that in nature there exists no durable vertical current of this kind. However, the streamlines of every turbulent current can be resolved into horizontal and vertical displacements, and thus every eddy and the whole turbulent current can be put together out of such elementary components. The present treatment of the hypothetical vertical air motion, an attempt at a general characterization, is to be extended in the following also to the general case of oblique air motion. In this way we shall be able by the aid of observations and deductions to approximate some of the basic principles of the mathematical theory of particle motion in currents.

In summary, the speed of the ascending air current necessary to keep the particles floating at constant altitude is just their fall velocity in stagnant air. At the same time, this is the least velocity sufficient to lift the particle off the ground. A stream of smaller velocity is unable to move the particle, whereas a swifter current will keep on lifting the grain to ever greater altitudes.

Even in stagnant air, the fact that the particle falls at constant speed instead of being constantly accelerated by the gravity force is due to the drag exerted by the molecules. The settling particle collides with enormous numbers of gas molecules, and although the latter are easily pushed aside, owing to their minute mass, they nevertheless have a braking effect on the grain of dust. With the increase of the fall velocity, the collisions with the gas molecules become more vehement, so that an equilibrium is established between the downward pull of the gravity force and the drag („friction") of the molecules, and from there on the fall velocity remains constant.

The case is different if the air moves upward at a rate lower than the settling velocity of the particle. In this case the collisions with the molecules are insufficient to keep the particle at constant altitude wherefore it commences slowly to sink. The relative velocity of the particle with respect to the air current remains the same (this is the condition for constant fall velocity), but the resultant velocity composed of the air motion and the falling of the particle with respect to the air current will now have a downward component.

If the velocity of the upward current is greater than the fall velocity of the particle, the latter will keep on rising, although it is invariably moving downwards with respect to the gas molecules. In the case of very fine dust and very great current velocity the rate of rising of the particles will practically reach that of the air current.

After the beginning of the process of settling, the velocity of the particle and the drag of the molecules change from zero to a certain value which remains constant in the course of the further history of the process. This constant speed may be widely different if related to the ground, but it is always the same as related to the gas molecules. Thus, the rising of the air current is invariably swifter than that of the suspended particle. As a result, there is no mixing of particles of identical size, and even the mixing that takes place has a direction different from that of the gas molecules, as will be expounded later.

The above considerations concerning the motion of dust particles were referred to the rather narrow case of the vertical air current. Now there arises the question as to what makes the wind, felt to be blowing horizontally, capable of lifting and transporting dust particles. This ability is due to the fact that wind is a turbulent, eddying current, whose streamlines have also vertical lifting components. However, as the air motion in the turbulent current is predominantly horizontal, we must now direct our attention to the lifting power of obliquely streaming molecules.

The effect of an air current rising at an angle other than vertical, the displacement of the particle can be determined by a simple construction of vector composition. For instance, to keep floating a particle of 0,05 mm diameter, a vertically rising air stream of the velocity $v_1=16$ cm/sec is necessary. If the angle of ascent of the air current decreases to 45° as measured against the horizontal plane, the velocity must increase to 22.6 cm/sec to keep the particle at constant altitude. In the process, the particle will be displaced also horizontally, namely by the amount of 16 cm a second. *(a_1.) (Fig. 7.).* The displacement of the trajectory of the particle as related to the trajectories of the air molecules is 22,6 cm *(b_2)*. However, this displacement does not equal the actual displacement of the particle against the molecules, as was the case with the vertical air current, *(b_1)*, since the particle will, owing to the horizontal component of the motion, be dragged along to a certain extent by the molecules. The flatter the angle of ascent of the air current, the greater the horizontal component of the motion belonging to the same value of the vertical component, that is, the greater the current velocity necessary to keep up the particle *(v_2, v_3)*; however, the relative displacement of the particle against the molecules *(k)* is unchanged. The figure indicates that in a strictly horizontal air motion the particles retain their altitude only in the practically impossible case of infinite current velocity; nevertheless, in an exceedingly swift horizontal air current the streamlines and the trajectories of the particles will practically coincide, and also the velocities of the two bodies will be practically equal.

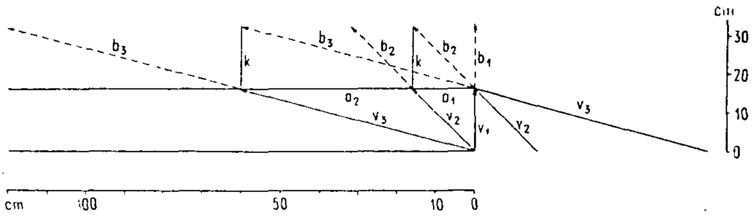


Fig. 7.

If the angle of ascent of the current is less than 90° and its velocity greater than the minimum needed to keep up the dust particles, the latter will always rise along trajectories slightly flatter than the streamlines. (Line *c* of *Fig. 8.)*. The two paths will coincide only in the case of infinitely great velocity or of very small particles.

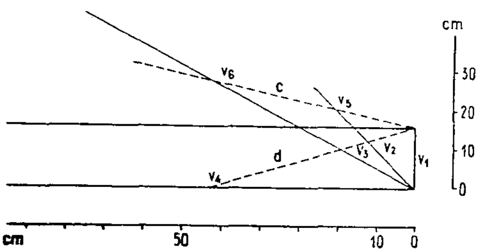


Fig. 8.

If at a given angle of ascent the velocity of the air current is less than the critical value, the particle will settle along an oblique trajectory. (Line *d*). The latter is the nearer the vertical, the smaller the velocity of the stream. The rising or falling trajectories of the particles may coincide even if the angle of ascent of the current varies, provided its velocity varies accordingly. (See the point of intersection of the lines *c* and *d*.)

Fig. 9. represents the trajectories of grains of different size under identical streaming conditions. The current rises at an angle of 45°, at velocities of v_1 and v_2, respectively. In the case of the velocity v_1, a particle of 0,06 mm diameter proceeds horizontally, particles ranging from 0,02 to 0,05 mm are

rising, whereas particles of 0,1 mm size are dropping at a steep angle. It the current velocity increases to v_2, all particles begin to rise except those of 0,1 mm diameter which move in the horizontal.

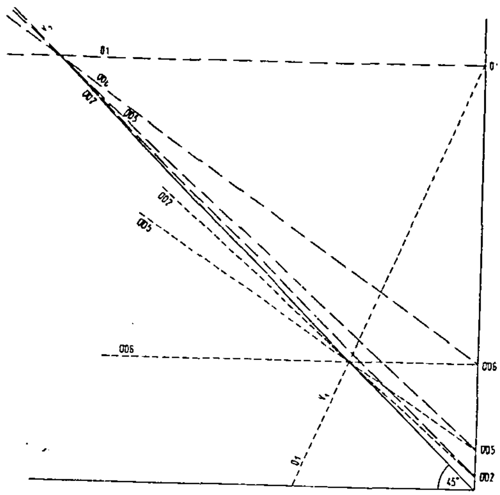


Fig. 9.

Since in nature both velocity and direction of the current are in a constant change, complicated trajectories are being realized in the process of transport. However, the essential point is that even a turbulent stream cannot exert a lifting force except if it attains the critical velocity corresponding to its angle of ascent. Furthermore, a durable transport can take place only if this state of things is itself durable, that is, if it is repeated at an appropriate frequency through an extended interval of time. The question as to what current velocity is necessary to exert such a lifting force, as well as the problem of the relation lifting power vs, wind velocity can be answered only by experience. Mesurements imply that suspended systems containing particles of 0,1 to 0,2 mm besides the dust fraction have been carried to considerable distances by winds of 15 to 20 cm/sec velocity.

4. SPATIAL RELATIONS OF BLOWOUT, TRANSPORT AND DEPOSITION.

After having been blown out from some accumulation of debris, a grain aggregate of mixed size is separated into a readily floating, mobile finegrained fraction whose settling is opposed by a considerable drag of the medium, and into a coarser-grained fraction generally moving along by rolling along the surface of the Earth. The tracing of the history of the two fractions and the changes of state of the depositing medium throughout a single elementary phase of sedimentation leads one to the following conclusions.

The rolled fraction is characterized by the following features: it moves in the plane of the relief, it possesses a well-defined kinetic energy and there is a direct relationship between the distance traveled and the energy consumed by the motion; owing to friction, the rolled particles come to an immediate halt as soon as the moving force ceases. Hence, the distance traveled can be determined if the transporting energy is known.

On the other hand, the floated fraction is lifted off the ground, whereby it gains besides its kinetic energy also a certain amount of potential energy. The fact that the floated particle is in possession of both kinds of energy has the consequence that the floated fraction cannot possibly settle in the zone across which it is transported. Between the distance travelled and the moving energy there is no direct relation; the motion does not cease as soon as the moving energy is spent. The potential energy is equivalent to a certain altitude, equalling in our case the altitude attained by the floated fraction in the course of its transport. This is the altitude that, after the air motion ceases, defines the layer of air to be termed the zone of depostition.

The significance of the zone of deposition is especially clear in the case of grains of good floating ability. After the immediate drop-out of the coarser grains, the settling of the dust particles takes place even in totally immobile air at a rate at least three times, and under a grain size of 0,02 mm even 17 times slower than that of the coarser grains. In consequence, dust-bearing and dust-free zones are developed in the transporting medium. The conditions are made clear by *Fig. 10.*

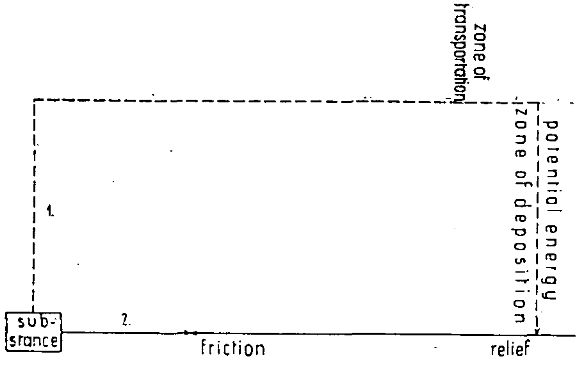


Fig. 10. 1. Path of suspended fraction.
2. Path of rolled fraction.

Of course, this sketch is no attempt at showing the actual path of the transporting wind or at the simplification of atmospheric phenomena. It only presents the elementary consequences of the process of transport. The trajectories realized in nature depend upon the caprices of the atmosphere, but they do not affect the final results. The most important condition for dust accumulation is the development of a zone of deposition, in the broadest continental as well as in the narrowest local relation. Now this condition may be satisfied under widely different atmospheric circumstances. Two main types of the possible atmospheric conditions were already recognized by Z. RÓNA (17, 18) in connection with the dust depositions in the years 1896 and 1901. In his opinion, the dust deposition of the year 1896, whose dust material is thought to have arrived from the sand steppe Deliblát, was due to an exceptionally vehement storm in that region. The dust was carried away by the outblowing wind and deposited later mostly in Transdanubia. Consequently, in this case, although from the aeronomical point of view these three processes took place within a single atmospheric domain, in the sedimentological sense we must distinguish several zones within this unit, the dimensions and properties of which were determined by the vehemence of the blowout, the force and direction of the air current etc.

On the other hand, in the case of the dust deposition of 1901 whose material was of Saharan provenience, transport was effected in RÓNA's opinion only in the first phase of the process by the outblowing wind. The dust, lifted to considerable altitude, was taken over by a high-altitude wind system, independent of the previous one. The trajectory of the particles did not essentially differ from the one described above, but here the zones of transport and deposition could be distinguished also on an aeronomical basis, since the limit of the two zones coincided with the limit of two independent wind systems.

5. THE FACTORS GOVERNING THE SORTING OF SUSPENDED MATERIAL IN AIR AND WATER.

Of decisive significance for the further treatment of eolian sedimentation is the paradoxical fact that the suspended matter, the floating dust not infrequently carried to distances of several thousand kilometres, attains but seldom such a high grade of sorting as would be expected in the knowledge of the essential differences in settling velocity. There occur in the grain assemblage besides the fraction below 0,05 mm also coarser grains. It is a quite general case that the finer grains are accompanied by numerous particles ranging from 0,05 to 0,1 mm, frequently even by some grains up to 0,5 mm. These, although in a steadily decreasing percentage, follow the fraction under 0,05 mm all the way in a number of instances.

The table below shows the grain size distribution of one of the dust samples of the fall at Szeged in 1941, as determined by I. MIHÁLTZ (14). (Szeged, the roof terrace of the University building.)

0,0— 0,0005	0,0005— 0,001	0,001— 0,002	0,002— 0,005	0,005— 0,01	0,02— 0,02	0,02— 0 05	0,05— 0,1	0,1— 0,2	0,2— 0,5	mm Ø
1,01	2,8	4,03	4,87	6,99	16,0	58,0	3,07	2,33	0,85	weight per cent

According to SCHAFARZIK, the dust settled in 1901, also mostly of Saharan origin, consisted predominantly of grains of 0,013 to 0,04 mm size, but a few grains were close to 0,067 mm, whereas in the sample from Váchartyán even a particle of 0,11 mm diameter was encountered. (19). BECKE has published a table on several dust samples fallen in Austria at about the same time. The table presented the predominant and the maximum grain size. It is reproduced below together with the data of HÄPKE from Bremen, of BARAC from Fiume and of SCHAFARZIK from Váchartyán.

Locality	Predominant fraction Ø mm	Maximum grain size
Kufstein	0,001 — 0,03	0,08
Zell am See	0,001 — 0,02	0,08
Judenburg	0,001 — 0,03	?
Greifenburg	0,001 — 0,03	0,13?
Arnoldstein	0,001 — 0,025	0,05
Kirchbach	0,001 — 0,032	0,1
Pontafel	0,001 — 0,03	0,11?
Tarvis	0,001 — 0,03	0,07
Görz	0,001 — 0,025	0,075
Lessina 1901	0,001 — 0,02	0,07
Lessina 1879	0,001 — 0,03	0,07
Bremen	0,001 —	0,1
Fiume	0,001 — 0,051	0,113
Váchartyán	0,0013— 0,04	0,11

These analyses were performed by counting out the grains under the microscope. No weight percents were calculated, wherefore the predominant grain size fraction is displaced somewhat towards the 0,001 mm diametre; the number of the grains is greatest in that fraction. A similar distribution is obtained, however, if the latest mechanical analyses of wind-transported dust are recomputed to yield grain numbers instead of weight percents.

Finally, let us cite an eolian dust analysis likewise performed with up-to-date techniques: that of SWINEFORD and FRYE (20) performed on a sample from Kansas (1939).

0,0— 0.00098	0,00098— 0.00195	0,00195— 0.0039	0,0039— 0.0078	0,0078— 0.0156	0,0156— 0.0312	mm Ø
5,55	2,67	5,31	3,89	5,63	24,41	weight per cent

0,0312— 0.0625	0,0625— 0.0125	0,125— 0.25	0,25— 0,5	0,5— 1.0	1,0— 2.0	mm Ø
41,85	8,45	1,64	0,38	0,19	0,04	weight per cent

Consequently, the majority of eolian dusts, even the very well-sorted and most carefully collected samples, indisputably contain grains larger than 0,05 mm. In this connection there arises the problem as to why in the majority of cases no complete sorting of the fraction of fair floating ability is arrived at in the course of floating?

Of course, the two fractions are mixed to begin with since the intensity of the outblowing current is not of the critical value that ensures just the floating of the dust particles, but considerably stronger, so strong that it carries off also grains above 0,1 mm size. The sorting is then taking place in the course of floating, and it tends towards an ever greater completeness, as the floating material gradually loses the more coarse grains. However, since coarser grains occur even in the best-sorted dust, the transporting capacity of the air current must be related also to the amount of energy necessary to to carry the coarser grains, as even a single coarser grain can be transported only if the conditions of its lifting and floating are satisfied.

On the basis of MIHÁLTZ's data (14) we can compute the amount of suspended matter deposited in the central area of the town Szeged in 1941.

The total mass amounted to 27 metric tons, in the following distribution:

140 kilograms of medium-grained sand, 0,2—05 mm,

620 kilograms of fine sand, 0,1—0,2 mm,

1,4 metric ton of fine sand, 0,05—0,1 mm,

24,8 metric tons of dust below 0.05 mm.

In all, the amount of the fraction of fair floating ability is a round 25 metric tons, that of the fraction of poor floating ability, 2,2 tons.

Now since the presence of even a single coarser grain indicates the acting of a lifting current of excess power, it is to be assumed with good reason that the fairly floating grains under 0,05 mm are trasnported to the locality where the zone of deposition is developed by a strong wind without or almost without loss. Hence, these grains constitute the unchanging or hardly changing fraction of the suspended group. For this reason, to distinguish these grains from the coarser ones, we call them the basic fraction, whereas the coarser grains are termed accessory fraction. In a strong wind, the grains below 0,05 mm merge almost completely with the transporting medium, and in the powerful current they follow the trajectories of the streaming gas molecules (see *Fig. 9.*).

According to the results of analysis of the dust fallen in this country in the year 1941, also the complete sorting of the suspended dust, resulting in nothing but the basic fraction, is possible. However, this was a special local phenomenon that took place in the area of deposition, after the development of the general conditions of settling, under quieter circumstances. We shall yet return to the discussion of this point.

On considering the process of transport, the presence of the coarser grains suggests that the wind, while it transports, unavoidably creates also the conditions for the scattering of the grains. In the course of this scattering, the grains of higher fall velocity are dropped first. This process is due to the temporary cessation of the lifting force, caused by an involved combination of factors, independently of the changes of the wind velocity. The process can be easily interpreted on the assumption that the entire air mass streaming in the zone of transportation is a disperse system which is unmixed time and again into the gas on the one hand and the aggregate of settling particles on the other. In the disperse state, the lot of the grains forms a mixture with the gas molecules in which no sorting or spatial segregation is at all possible. However, in the state of settling the grains become unmixed and begin to fall, and the grains arriving at the lower boundary of the air mass leave the system for good. It is apparent that it is the coarse grains of high falling velocity which are dropped at the greatest rate off the zone of transportation. However, the rate of decrease is determined among others also by the thickness of the layer of transportation, since the longer the way of settling from the top of the system to the bottom of the same, the more probable is a continued transportation, or, restricting the statement to the simplified case, the possibility of further dispersion.

In summary, the transport and sorting of the grains can take place simultaneously only if the transporting air mass creates conditions in which the gradual dropping off of the coarser grains is possible even without the abating of the current, that is, if the transport is of a double nature.

The sorting that came about in this way does not fit into our general ideas on sorting, according to which the process is solely due to the gradual abating of the transporting force, the slowing-down of the current, that is, essentially to the cessation of transport as related to some grain size category or other. The above process is a consequence of the motion of the transporting medium, that is, of the process of transportation itself, unable to reproduce in all details the conditions of lifting in the course of the periodic rise and fall of the transporting molecules. In a water stream a process of this kind takes place only if the velocity of the transporting current slackens — obviously for some external reason such as a change of the discharge or of the bed of the stream — and the transportation of certain grain fractions ceases as a consequence. This phenomenon is to be considered and termed an external, velocity-dependent sorting. On the other hand, the sorting of the material in eolian suspension is an internal process, a consequence of the nature of the transport, taking place under any current velocity, wherefore it is of a velocity-independent nature.

In all, the transportation in eolian suspensions possesses the paradoxical property of partial lifting inertia, resulting in sorting even if the velocity of the transporting current increases. This phenomenon is a predominant factor of rapid and efficient sorting: nevertheless, it is not expounded in the literature of waste transport in water streams. It is true, though, that its significance is much harder to recognize there. The reason for this is that its influence is manifested only if the transport is taking place along a path of high altitude, when there is no basement (river bed or relief) close at hand from which the repeated sweeping-off of the once dropped particles would be possible.

Here, vertical turbulence seems to be no satisfactory explanation for the mechanism of transportation. Namely, if this condition should prevail, the medium would not only lift but also drop all the grains in a single revolution of a vortex. It is therefore to be assumed that in a given section the number of the grains being lifted is invariably greater than that of the grains being dropped; it is only in this way that the gradual scattering can be interpreted.

Thus, if a vehement gust of wind catches up a lot of unbound sand and carries it off on an ascending path, it drops back in a short time most of the coarse matter even if the wind velocity does not decrease at all. At the same time it keeps on carrying, as a matter of course, numerous coarser grains of exceptional position, even if in a steadily decreasing amount. It follows hence that the development of a well-sorted, fine dust is by no means a necessary consequence of the abatement of the transporting energy. The coarse grains left attest that the transporting capacity of the wind is not at all reduced. The stormy high wind, after it has lost much of its coarse-grained freight without loss of velocity, much like a leaking cart, becomes a mostly unexpolited transporting agent.

In the case of dust depositions of continental scope, the dropping of the coarser grains takes place for the most part in the neighbourhod of the blowout area, whereas the rest is scattered along a path of several hundred kilometres length, resulting in a noticeable deposition of sediment. *(Fig. 26.)*. However, the relatively enriched dust content is dropped in more narrowly defined belts or spots, according to observations in those places where the transporting current reaches the border of a different wind system, strikes against the same and is broken up thereby. Hence, in cases like this the deposition of the dust is the consequence of a collision. *(Figs. 19.* and *21.)*. In these cases the vertical currents forcing the dust to the ground also play a role not to be unterrated.

It follows further from the outlined interpretation of transport and sorting that the definitions concerning the distance of transportability of grains of a given diameter in a current of a given velocity do not make much sense. Udden has determined the distance to which a single finer and a single coarser grain can be carried by a wind of medium strength. It is a fact that a strong wind may carry a grain of 0,1 mm diameter to distances as much as and even exceeding 500 km, provided the individual trajectory of the particle – the fortunate combination of lifting and horizontal forces – permits. On the other hand, if the conditions are unfavorable, the same grain may become dropped not farther than one kilometre away. Obviously, a wind of medium force is of equal transporting capacity everywhere along is of equal transporting capacity everywhere along its course; in spite of that, it constantly deposits part of the coarser grains, whereas it constantly keeps up the rest. There is no sense in studying the distance of transportability of a single grain; the solution must be looked for in the statistical treatment of the problem, in the consideration of the predominant grain diameter. A wind of greater force drops along a given distance a smaller number of grains, particularly of coarse grains, that is, the material transported to a given target area is of a greater predominant grain size besides being of a greater mass. In a weaker wind the predominant grain size is smaller.

An inquiry into the reason why the grains of silt and clay size are subordinate as related to the coarser grains reveals that this feature is not due any more to the sorting action of the transporting wind. Independently of the distance traveled, the dust will not become finer after having reached a certain limit. It is a general observation that eolian dust and loess contain relatively little material under 0,01 mm grain size, that is, their grain size distribution has a lower limit almost as sharp as the upper one. This circumstance may be retraced to the reason that the eolian dust is the product of redeposition of sediments containing little clay, that is, furnishing few grains of clay size on blowout. The detailed dust deposition study of MIHÁLTZ from 1941 (14) which, being based on a series of analyses, also reflects the process of sorting, gives a convincing proof of this statement. The composition of the material deposited in Hungary in 1941, whose grain size became finer from the south to the north, reveals the following: in the dust collected at Miskolc, of 0,01 to 0,02 mm predominant grain size, the abundance of grains under 0,002 mm was 2,68 percent, in the sample from Budapest, of the same predominant grain size, it was 6,69 percent. At the same time there was 7,84 percent of clay in the dust fallen onto the University of Szeged, whose predominant grain size was 0,02—0,05 mm, that is, it contained more finer material than the finer dust samples. This is an irrefutable proof of the fact that the original blownout material contained no floating clay particles, and the very little material of this grain size category was transported adhering to the larger grains. In the opposite case, its amount ought to have increased from south to north in the suspended material, just as the fractions of 0,002 to 0,005 and 0,005 to 0,01 millimetres have increased. However, the abundance of these latter fractions was greater in the Miskolc and Budapest samples than in the material from Szeged; in the case of the 0,002 to 0,005 mm fraction the increase was from 6,4 to 9,7 percent, in that of the fraction of 0,005 to 0,01 mm from 7,3 to 21,8 per cent. This shows that the blown-out material contained relatively many independently floating grains of 0,005 to 0,01 mm size and relatively few of 0,002 to 0,005 mm diameter; the latter settled mainly in the last stage, in the north, in the expected sequence of deposition.

The lack of finest grains in the blownout material is explained by the bounded material-producing capacity of air. The presumably most general and most frequent base material of eolian dust is loose wind-blown sand containing little fine-grained mateiral. Hence, the stirring-up of clay particles is impossible to begin with, and in the lack of such no suspension containing clay-size material can possibly develop. Would the materialproducing capacity, the „solvency" of air be as unlimited as that of water, there would be no sharp sorting confined to the 0,01 to 0,05 mm fraction, so well-known in connection with eolian dust and with loess, representing the average of eolian dusts; only the upper limit at 0,05 mm of these sediments would be so sharp, and in the lower ranges there would be a much flatter, much more silt-like grain size distribution curve. The relative abundance of the fraction of 0,01 to 0,05 mm diameter would then decrease from 50—70 percent to 10—20 percent.

In summary, a study of the factors bringing about the sorting of eolian dust leads one to the following conclusions:

The remarkably hight degree of sorting of eolian dust and the predominance of the characteristic grain size of 0,01 to 0,05 mm is the result of three factors: a characteristic property of the resistance of the air molecules, the partial lifting inertia caused by the double nature of the transportation and entailing a rapid and intense internal sorting, and the original grain size distribution of the blown-out material.

However, this explanation is not satisfactory as regards loess, because in this case the sorting must be studied also in the course of the systematic deposition of this sediment. Even the most efficient mechanism of sorting is of no avail if the sedimentation is not continuous and unchanged, or if it is incapable of repetition under indentical circumstances. The loesses of geological importance were formed out of the material of numerous dust depositions, and consequently their sorting and petrographical features can to some extent be considered as averages. The fact itself that the average grain size distribution of loess does not differ significantly from that of the dust deposited in a single event shows that the sedimentation from eolian suspension is capable of being repeated a considerable number of times. This repetition is, however, bound to certain well-defined features, which can by no means be independent of the factors governing the sorting. In repetition, two groups of phenomena are interacting: on the one hand, sorting, which is the expression of the internal motions of the air current and entails the well-defined grain size distribution, and on the other, the repetition of the motion of the medium, resulting necessarily in a transportation at high altitude, dependent on aeronomical factors acting from the outside.

In summary, loess is formed out of suspended material whose grain size distribution has, owing to the nature of the blowout, transport and sorting, an exceptionally high probability of repetition. In other words, this means that the outblowing, transporting and sorting action is of such a nature that it tends to turn any outblown and suspended material into a dust of characteristic grain size distribution.

This interpretation of the genesis of loess has the consequence that the sediments or rocks formed out of eolian dust may be suitable for studies of a general nature, freed of random local influences, on the physics and dynamics of the Earth and of the atmosphere as a whole. This problem was already brought up in connection with the dependence of fall velocity on the force of gravity and the influence of this dependence on the upper grain-size limit of sorting. *(Fig. 6.)* On forming the average grain size distributions of eolian dust deposits and composing a generalized cycle of sedimentation therefrom, it becomes clear after having corrected for the scatter of the grain size distribution that the latter can be interpreted also purely in terms of the density of the medium and the intensity of the gravity field. *(Fig. 11.)*. This fact has a principal significance, in the first place as regards the study of the gravity, Earth density and Earth radius of ancient geological periods. It permits namely to analyze, by studying the grain size distribution of ancient loesses which have presumably

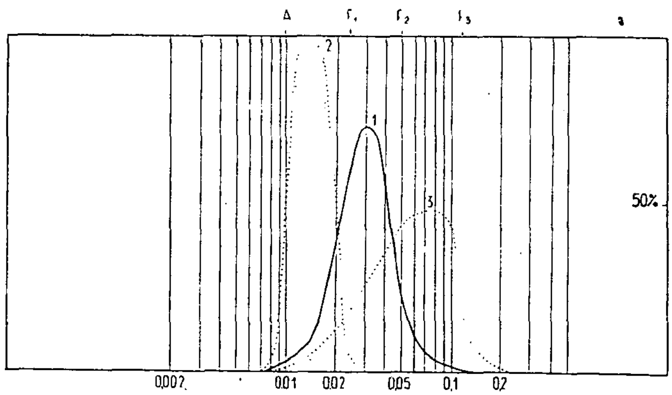


Fig. 11. Interpretation of the grain size distribution of loess *vs.* gravity acceleration.
A: lower limit of sorting
F_1 F_2 F_3: upper limit of sorting
1. Typical loess (according to I. Lányi—Mihályi)
2., 3. Typical loess developed under a gravity acceleration ten times as great and ten times as small resp.

formed in the Devonian and Triassic, as well as of other ancient eolian dust deposits, the intensity of the Earth's ancient gravity field, having an important bearing of the problem whether the Earth is expanding or contracting.

The situation is entirely different with fluviatile deposits. These are formed in a medium moving along the surface of the Earth, and they are sorted by a process much influenced by the ever changing local conditions of relief and discharge, that is, by the changes of velocity. Therefore, as the formation of the fluviatile deposits depends on a number of random factors that cannot be distinguished from the general dynamical ones, these deposits do not permit any conclusions of the general nature mentioned above. In the following we shall also consider why this prevails also for sea water, which otherwise is capable of depositing loess-like sediments.

It is beyond doubt that one of the conditions of the poorer sorting of the finer aquatic sediments (silt, mud, clay) as related to the sorting of eolian dust is the wider compass of the material production of water. Another factor is, as stated by STOKES's law, the greater density of the medium, resulting in a narrowing of the chances of sorting of the transported grains. Furthermore, in water there occurs no sudden increase of the drag at a critical velocity, which would permit the intenser separation of some of the grain size fractions. Also, in one of the large groups of streaming-water deposition, in the case of streams, there is not manifested the influence of the above-described partial lifting inertia, since the streaming water can repeatedly pick up the grains dropped onto the bottom of the stream bed or onto the floodplain, provided the velocity of the flow does not decrease. Consequently, in streams even that degree of sorting of the suspended material is impossible which would result from the differences of settling velocities along a path similar to the path of air transport, that is, from a sorting in the „eolian manner". In streaming water, the segregation of the coarser grains from a given aggregate commences only if the velocity of the transporting current slackens, that is, if the state of absolute untransportability sets in for the larger grain size fractions. In this case, the segregated fraction can be ideally sorted, provided the decrease of velocity is slow enough, better even than the fraction which goes on being suspended. Since however in streams and in the flood areas the changes of velocity of the current within a given area of deposition are dependent on the ever changing conditions of water level and bed development, also the grain size distribution of the dropped fraction varies, that is, no uniformly sorted sediment deposited from suspended material can form in this way, at least not in a thick layer and general extension.

The situation is different in sea water, where the currents flow in distinct layers (cold and warm currents, the layering of fresh water flowing in from the continental areas). Here, the influence of the lifting inertia has a free play and it promotes the sorting of the grains within the limits prescribed by the settling velocity. However, for a sediment of complete sorting similar to that of loess (silt) to form, — no matter whether we consider the fraction dropped in the sourse of transport or the fraction which remains suspended but settles later on as a „final product" — it is not less necessary that the state of absolute untransportability should set in, as a result of the slackening of stream velocity, which results in its turn in zonal distribution and continuous sedimentation.

This condition is readily fulfilled in sea water, as the streaming is much more uniform and better-regulated, just like in some correctly operated sludge tank.

The role played by these dynamical factors is decisive even if the role of the reworked loess and of the dust falling directly into the ocean is taken into account as well.

However, just for this reason, silt cannot be the only well-sorted fine sediment in the oceans, whereas in the air every outblown mateiral ends up in the final reckoning in the dust state, owing to the nature of the transport and sorting. That is why dust is of a world-wide extension. In sea water, also other grain assemblages can develop, in dependence of the local stream velocity distribution, that possess a not less excellent sorting.

In summary, we have to mention among the factors of sorting in the general case also the steadiness of the current, which in the case of water may sometimes be of decisive importance.

6. PHENOMENA OF SEDIMENT FORMATION CONNECTED WITH LOESS.

In the foregoing considerations the settling velocity of the grains and the analyses of recent dust deposits were taken into account in the first place. We have sketched the circumstances of dust deposition, the presumable composition of the outflown material, the force of the outblowing wind, the process of internal sorting, the mechanism of transportation and deposition connected therewith. Now let us pass to the analysis of some observations concerning loess. There are known some phenomena of deposition and grain size distribution which merit some attention from the point of view of elucidating the mechanism of formation. A phenomenon of this sort is the horizontal, relief-dependent change of the grain size distribution of loess deposits following the undulations of the relief, as well as some cases of occurrence of sediments transitional between loess and wind-blown sand.

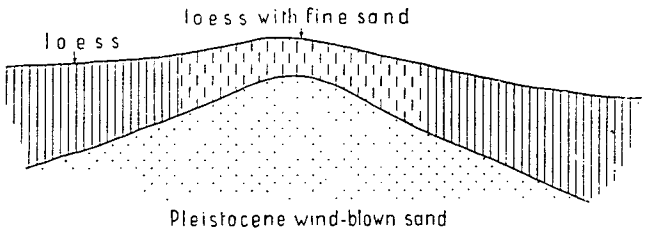


Fig. 12.

The loess deposits of the Great Hungarian Plains mostly overlie an undulous relief, generally that of Pleistocene wind-blown sand, wherefore also the surface of the loess is undulous. In the wave troughs the thickness of the loess is invariably greater, indicating that the loess blanket has to some extent smoothed out the relief differences between the crests and flanks of the dunes. It is an essential feature that in these cases the loess found on top of the crests is of a mostly coarser grain size distribution. *Fig. 12.* represents a loess cover overlying wind-blown sand.

In one of the investigated disclosures of this kind, SW of Kiskundorozsma, by the highroad tofards Kiskunhalas, there is on top of a loess-covered erosional island, in an elevated area of some 3 metres relative altitude a loose loess with fine sand containing dry-land *Gasteropods,* whereas in the deeper-lying parts of the relief there is a more massive, slightly „silty" loess with abundant *Limnaea* and *Planorbis* specimens (*Fig. 13., Fig. 14,* Curves B_1 and A_1, respectively). The disclosure is continuous in a length of some 50 metres. The limit of the drenched and dry-land varieties of loess is blurred. The area was studied in some detail by I. Dobos-Molnár, who drilled a borehole of 10 metres' depth on top of the rise and found mud and clay in a depth of 5 metres.

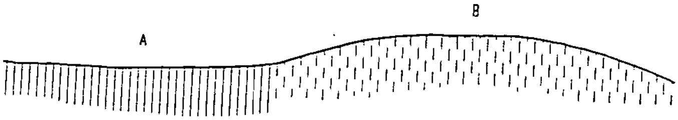


Fig. 13.

Another disclosure is known from beside the road connecting Baja and Csávoly. This loess is purely continental and overlies a deposit of wind-blown sand. The disclosure is 15 metres long and the rise is 2 metres above the nearby hollows. The disclosure encompasses also the underlying wind-blown sand. Samples were collected at two points, at identical distances from the surface of the sand, to exclude the sampling of transitional deposits. Also here the shift of the grain size distribution from the rise towards the hollow is of the same nature as in the foregoing example. (*Fig. 14.,* Curves B_2 and A_2.)

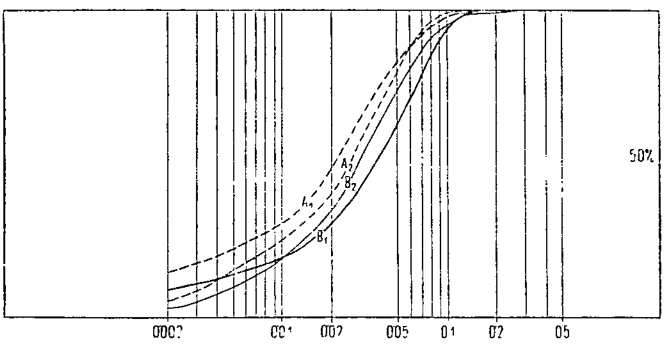


Fig. 14.

This regular variation of the grain size distribution can be explained in the following way: the elevations of the undulous terrain influence the working capacity of the near-surface wind. The rises decrease the cross section of the stream channel and thus increase the velocity of the medium; above the hollows, the converse is true. On the tops there is also some suction.

It is by this near-surface current of variable working capacity that the settling dust is sorted. It is essential to stress that the near-surface air only takes a part in sorting and not in transportation. Namely, in the swifter current the coarser grains, that is, the grains of the accessory fraction, are just able to settle, whereas the finer grains of the basic fraction are swept aside and deposited in the hollows. The dust arriving above the hollows is deposited in its original grain size distribution (basic fraction plus accessory fraction). Consequently, a relative enrichment of the grains of the accessory fraction comes about around the crest, whereas the grains of the basic fraction are actually enriched in the hollow area.

The phenomenon is, as a matter of fact, a natural proof for the existence of the zone of deposition. It cannot be explained except by assuming that the transportation is effected by winds roaming at higher altitudes (zone of transportation) and that there is a quieter air layer more suitable to settling underneath (zone of deposition). Accordingly, the grains arrive from a greater altitude along more or less vertical paths, like snowflakes, and they are arranged as predestined by the relief. Should the transport be effected by a near-surface wind, the coarser grains would accumulate just in the hollows, since they would drop out of the weakening current there before arriving over the next elevation. This process is a peculiar case of the external type of sorting. It is presented by *Fig. 15.*

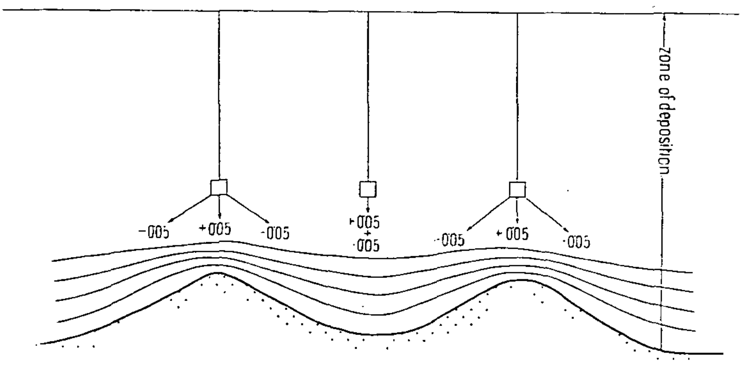


Fig. 15.

The described phenomenon suggests that the dust particles have arrived in the period of loess deposition along near-surface trajectories above the locality of settling, so that the conditions of transport along a path of high altitude do not hold for the process of their sorting. The blowout, which was according to our above results the consequence of a stronger wind, did not take place in the immediate neighbourhood of the area of deposition. The currents circulating here had essentially no transporting capacity and have apported no material, that is, the area was characterized by conditions of deposition.

These circumstances shed light in the first place on the structure of the winds present in the course of dust deposition near the surface, on the lack of any lifting tendency. Thus, for instance, according to Róna (17), in 1901 „the dust falling from higher regions was but thrown to the ground by the lower wind". In his terminology, „lower wind" means the sorting current and the „higher regions" mean the zone of transportation, also distinguishable in the aeronomical sense. Hence, a strong near-ground wind is by no means excluded from the process of dust settling; under such circumstances even the stirring-up of the particles on the ground and phenomena of less regular deposition are possible. The essential point is, however, that these events do not influence signicifantly the striking features of the process of formation; they obscure but slightly the completeness of the horizontal sorting in the investigated area. It can be stated further that in these cases the settling of the dust is final and not just a „rest". The lower wind, even if stormy, is but a concomitant phenomenon of deposition, by no means able to revert its course.

It is here that Udden's (21) observations concerning a deposition of similar nature of eolian dust in present times should be mentioned. Udden studied the material of North American dust depositions taken place in November 1894; January 1895 and February 1896 and he took into account also the circumstances of local arrangement of the deposit. The dust samples originated from an area covered with snow and ice. He found that the dust collected from the middle of the frozen Mississippi canal, far offshore in a plain area, contained fewer coarse grains. On the other hand, in localities where relief forms (riverbanks etc.) or buildings disturbed the current, less fine dust was able to settle.

We have constructed the grain size distribution graphs of five cited samples *(Fig. 16.)*. Samples 146., 150., and 156. were taken in plain areas, whereas samples 152. and 153. came from the riverbanks. The former correspond to the loess of the hollows, the latter to that of the elevations.

Udden has further found that the dust collected on top of the continental ice contained a larger proportion of coorse grains which in his opinion was obviously an admixture off the ground. The case was similar with some samples which were swept on by the wind after deposition and collected for instance in an ice crack. In this respect Udden cites six samples (144., 145., 147., 148., 149., and 151.) whose average grain size distribution we have computed and likewise presented on *Fig. 16.* The analyses were performed by the microscopic procedure but weight percents were calculated.

In connection with the dust deposition of the year 1941, Miháltz (14) also brings up the possibility of mixing with local substances. Close to the sampling locality of one of the Szeged samples there were spots of barren loess and in this sample there was found an unusually high, triple amount of carbonate. In Miháltz's opinion, dust stirred up locally could have become admixed to the dust transported from far away wherever there was a strong wind over dry ground in the neighbourhood of the locality of deposition. This is fairly plausible, for in the sense of the above considerations deposition takes place even if it is hampered by a relatively strong or even stormy near-surface wind, a „dust storm".

Since the accumulation of the dust may thus go hand in hand with mixing with local material, the mechanical and mineralogical constitution of the ground must be attributed a particular importance for the composition of the loess to be formed. This problem was raised by KRIVÁN (10) in the form of the notion of the different origin of loess and loessy sand. In his opision, loessy sand is

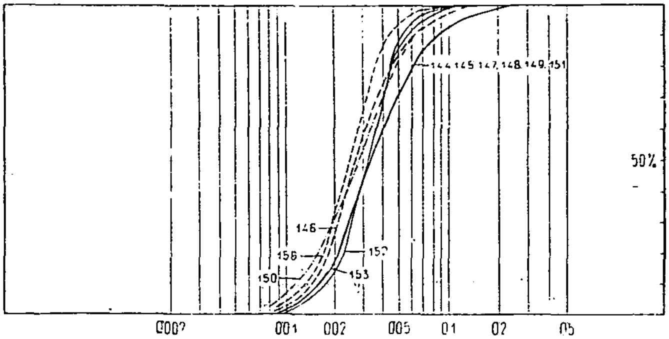


Fig. 16.

actually a mixture of local wind-blown sand and eolian dust from far away. This sediment is found frequently on top of wind-blown sand, merging vertically into loess. KRIVÁN explains the gradual refinement of the grain size by the covering of the free sand surface, by the gradual elimination of the possibility of mixing with sand.

The near-surface currents accompanying the dust depositions in present times warrant the assumption of a mixing of this sort. However, mixing is not less possible between finer and coarser local material and if the grain size distribution of the mixture presents no distinctive features proving the faraway origin of the dust fraction, the formation of the mixture in this way cannot be accepted as proved even if highly probable. Neither does the phenomenon of the evolution of the zone of deposition give any possibility of determining the absolute distance of the blowout locality without a profound study of the circumstances, based on a detailed material analysis.

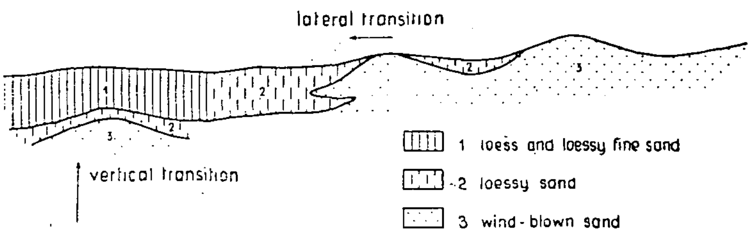


Fig. 17.

The situation is further complicated by the fact that the mixed deposits like loessy sand merge into loess not only in the vertical but also in the horizontal sense, in the manner of lateral facies (*Fig. 17.*). Our aim in the following will be to study the changes of the grain assemblage from the wind-blown sand towards the loess as well as the nature of the transitional deposits, in order to determine the laws to which the processes of local and mixed (local plus faraway) sediment formation are subject. For this purpose we have developed a technique of calculation serving the numerical expression of the kinship between different kinds of sediment.

7. THE PROBLEMS OF THE RELATION OF LOESS TO WIND-BLOWN SAND. THE NUMERICAL REPRESENTATION OF SEDIMENTARY FACIES.

As regards their grain size distribution, the transitional deposits are intermediate between loess and sand. In this country they occur in a number of localities, some of them in great extension, both above and underground. Their classification is due to MIHÁLTZ (12) and I. LÁNYI—MIHÁLYI (15). These authors distinguish two main groups: loess (0,02 to 0,05 mm diameter) and sand (0,1 to 0,2 mm diameter) on the one hand and transitions between loess and fine sand (0,05 to 0,1 mm diameter) on the other. The aptness of this distinction is proved by the fact that the grain size distribution graphs of loessy sand and sandy loess frequently exhibit two maxima owing to the lack of grains between 0,05 and 0,1 mm. The taller peak may be in the loess just as well as in the sand fraction. On the other hand, loessy fine sand and fine-sandy loess posses invariably single peaks, flatter than that of loess, shifted somewhat towards the grain size domain of fine sand *(Fig. 18.)*.

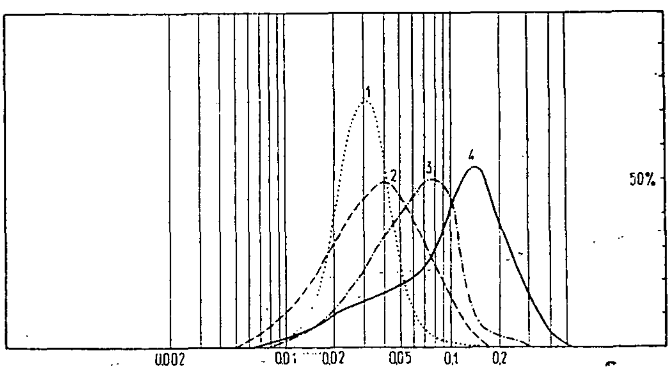


Fig. 18. Loess and transitory deposits according to I. LÁNYI—MIHÁLYI.
1. Typical loess
2. Loess with fine sand
3. Loessy fine sand
4. Two-peak laessy sand

In a summary sense, these formations are systems containing grains of opposed properties, of fair and poor floating ability, respectively. Previously, when we were concerned with a single sequence of sedimentation, we have found that the grains above 0,05 mm float in a strong current just as well as the dust particles do and that they may accompany the latter a long way, while the internal sorting of the suspended grain assemblage leads to the characteristic sequence of evolution, the enrichment of the basic fraction. Although the grain size distribution of the outblown sediment undergoes some necessary changes in the course of suspension, the change is the less, the closer we are to the locality of outblowing. Hence, in the early stages of sorting, especially if the outblown material consisted mostly of sand, there may be formed a mixture containing in a greater abundance grains both above and under 0,05 mm, which under the appropriate circumstances can be deposited in thein entirety. The multiple repetition of the process may lead to the accumulation of huge amounts of sediment. It is essentially this mode of formation that is to be called homogeneous, which means simply that the substance at hand is a sediment that travelled in suspension, a sandy eolian dust.

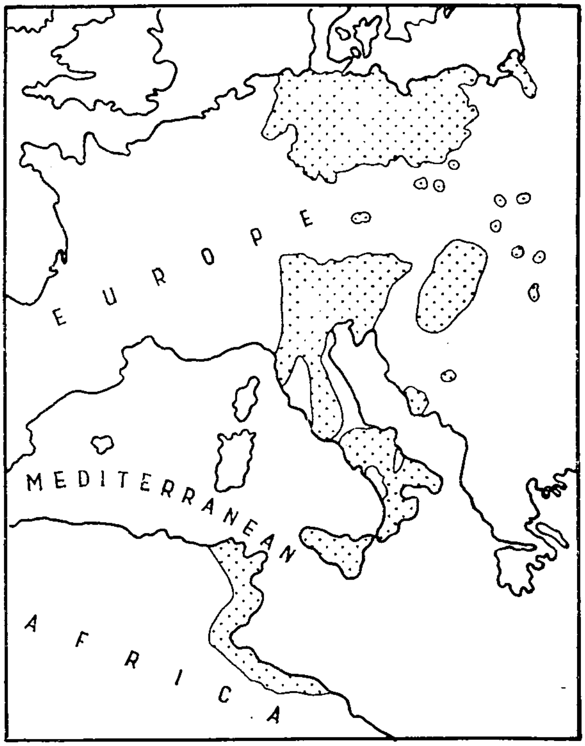


Fig. 19.

On the other hand, the alternation of layers of nearby wind-blown sand and longtransported eolian dust is to be termed a heterogeneous deposit.

The dust deposits of windblown-sand origin of the present times passed in the course of suspension withouth exception through the stage of „sandy" sorting. As far as we know there had been near the locality of outblowing dust depositions of early-stage dust, and it may even be said that this way of formation is an accompanying phenomenon of any dust deposition. However, the outblown material was not deposited in its entirety; on the contrary, it was distributed in several air masses and these fractions underwent a further development as independent systems, which travelled to different distances. The extension of the dust deposition of the year 1901 also shows this phenomenon. *(Fig. 19.,* stippled fields.) The dust deposition of 1941, described above, was essentially also the final stage of evolution of such a separated dustcloud, fallen under the dominancy of the conditions of deposition.

Of course, the breaking-up of the dust cloud and the loss due to deposition of some fragment or other does not contradict the former statement that the grains under 0,05 mm form an unchanging or hardly changing fraction of the suspended material all the way, up to the area of deposition. This remark refers to the sorting taking place in the course of floating and principally in the horizontal section of the path. However, the breakingup and the vertical travel of the dust cloud is a thoroughly different phenomenon involving a change of direction and it is not to be confused with the loss of material taking place in the course of transport. The mode and place of the breaking-up is incidental, whereas the loss of material and the process of evolution are subject to a fixed, uninterrupted schedule.

At a first glance, the concept of the „unchanged fraction" is questionable rather on the grounds that in some instances the 0,01 to 0,02 mm fraction is separated from the swifter-settling fraction of 0,02 to 0,05 mm. This happened e. g. in 1941. The process undoubtedly took place in the course of floating, but certainly in the downward section of the path, after the loss of the accessory grains. A segregation of this kind may take place anywhere in any phase of evolution, in the course of deposition and loss of velocity. The decrease of the velocity of transport does not only rend the individual grain size groups untransportable in the absolute sense, but it also hastens the process of internal sorting.

Our comprehensive *Fig. 20.* presents the sedimentation accompanied by breakup and segregation of the basic fraction in the sense expounded above. The essential point is, consequently, that the segregation within the basic group takes place under the influence, of the conditions of deposition. The radical alteration of the conditions of stream motion leads then necessarily to a general or periodically returning anomalous weakening of the force of the current, that is, it results in wide-amplitude fluctuations of the transporting capacity. While the material approaches the disturbed section of the path, the direction of the current also changes in the vertical sense. The disturbance that takes place can result not only in the loss of the accessory fraction but also in the breakup of the whole system, the segregation of the basic group. The remaining fractions may proceed further to short distances in the original direction, but they are relatively short-lived; the process is irreversible and it soon comes to an irrevocable end.

Observations show that the disturbed zones develop mostly along the line of contact of colliding wind systems (cyclone-anticyclone, 1941, 1942, 1896?). *(Fig. 21.).*

In *Fig. 21.,* the direction of progress of the dust deposition of 1941 and its longitudinal extension was indicated by an arrow. The original direction of the dust mass was a northerly one, but after the carrying cyclone hit an anticyclone, not only the structure and transporting capacity of the wind was changed but also the general direction of progress. In the section between blowout and deposition, no dust falling was observed anywhere, but some very slight deposition of sand is to be mentioned.

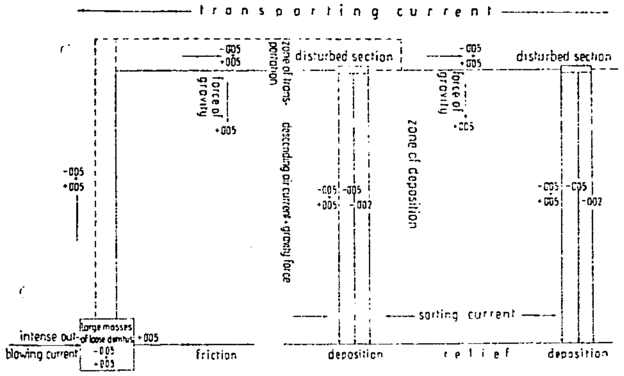


Fig. 20.

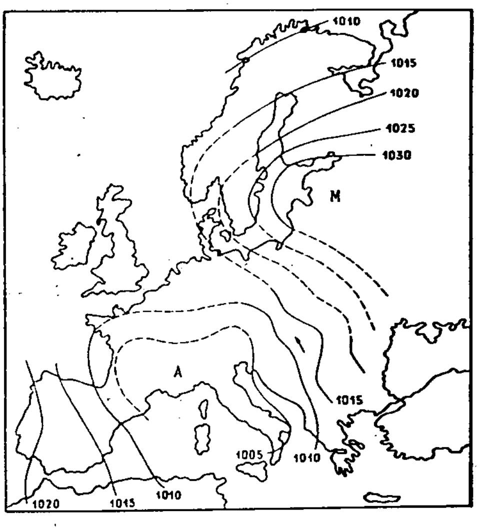


Fig. 21.

Coming back to the study of evolution of the grain assemblages, it shall be our aim to follow the change of composition, the internal sorting of the blown-out material with numerical accuracy from the moment of the blowout up to that of deposition, in order to clear the laws of formation of loessy sand and loessy fine sand, and in a concrete case, to study the problem as to what mode of origin (homogeneous or heterogeneous) is reflected by their constitution and further whether it is possible in the case of a given sediment source to establish kinship from wind-blown sand to loess *(Fig. 17.)*.

We have already mentioned that the turbulent stream carrying the grains has a lifting component in certain phases only, wherefore the lifting frequently alternates with falling in the system consisting of innumerable eddies. This circumstance results in the constant irreversible loss of some grains approaching the bottom of the swirling mass of gas, even without any loss of velocity. From the asemblage of grains, unevenly scattered in the process of transport, the grains of high fall velocity drop out first. However, in the lifting and dropping motion of the turbulent mass of air the process of the drop-out of certain grains occurs at the same probability level as it would in a process of uniform scattering and deposition.

The phenomenon may be illuminated by the following thought experiment. Let us consider a sand containing 10 percent of grains of 0,02 mm diameter, 20 of 0,05 mm diameter, 20 of 0,1 mm and 50 of 0,2 mm diameter, expressed in percents of the total number of grains (e. g. 100 grains). After the total blowout of the sand, the transport is effected by an air layer 50 m thick (zone of transport). This is considered a closed system and within this system we assume a complete mixing of the suspended grains and the air by the appropriate mixing current (state of equilibrium). However, this equilibrium is upset time and again and re-established by the rhythmic weakening and intensification of the current. Thus, the state of complete equilibrium alternates with a contrary state, under the dominance of which part of the grains are secluded from

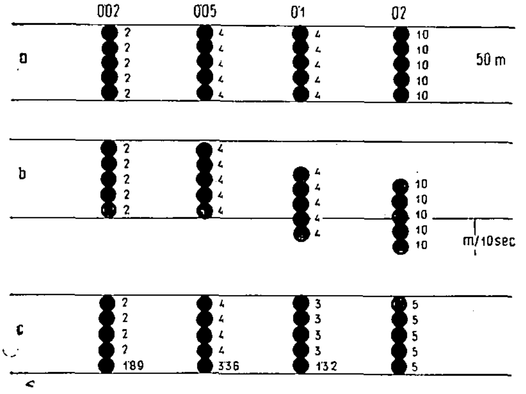


Fig. 22.

the system. This is called the phase of rest („state of no equilibrium"). Its duration is set at 10 seconds and we assume that for this period the air is at complete rest. Namely, the current necessary to keep up the grains of 0,05 mm size hinders, even if slightly, the settling of the grains of the accessory group. This effect influences primarily the smaller grain size classes of that group. However, as we are unable to determine the extent of slowing, we assume periods of complete rest for which we take simply the fall velocities determined in stagnant air.

Fig. 22. shows a complete cycle. The discs represent grains and the number of grains is obtained by multiplying the number of discs with the annexed number. Step „*a*" is the state of equilibrium (complete dispersion), step „*b*" is the ten-second period of rest and step „*c*" the reestablishing of equilibrium.

Owing to the ten seconds' complete rest, 50 percent of the 0,2 mm grains, falling 25 m, and 33,4 per cent of the grains of 0,1 mm, falling 16,7 m in ten seconds, drops out of the system, and settles. Of the grains of 0,05 mm 3,2 percent, of the 0,02 mm grains 1,1 percent is deposited. The reestablished state of equilibrium of step „*c*" finds therefore much less accessory grains and an almost unchanged amount of grains below 0,05 mm, that is, the latter are significantly enriched in the relative sense. The subsequent cycles of similar nature are not shown, but the result as expressed in percents of the total number of grains of the fraction that goes on floating is shown by the table below and by *Fig. 23.* Of course, later on these values must be converted into weight percent.

	0,02	0,05	0,1	0,2	mm diameter
start	10	20	20	50	percent
I. cycle	14,6	28.6	19.7	39.6	
II. cycle	19.6	37,5	17.7	25.0	
III. cycle	24.2	45.4	14.8	15.6	
IV. cycle	27.9	51.3	11.5	9.1	
V. cycle	30.8	55.5	8.6	5.1	

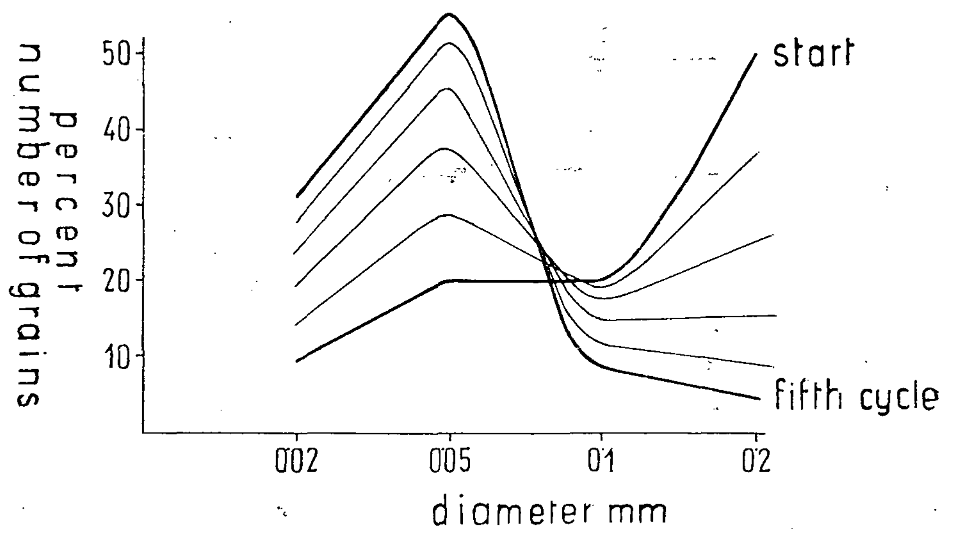


Fig. 23.

For the purpose of computation, we have made the following simple deduction: the thickness of the air layer stands in the same relation to the number of grains in step „*a*" (Sza) as the fall velocity to the number of grains dropping out of the system (Szb) in step „*b*" *(Fig. 24.)*:

$$\frac{V}{Sza} = \frac{e}{Szb}, \text{ whence } Szb = Sza \cdot \frac{e}{v}.$$

Since in the new stage of equilibrium *(„c")* the number of grains is $Szc = Sza - Szb$,

$$Szc = Sza - Sza \cdot \frac{e}{v}.$$

Within the same set of computations, *e/v* is a constant factor, and thus

$$Szc = Sza - Sza \cdot k.$$

We have deliberated from a number of aspects whether the calculated factors represent correctly the process taking place in nature (14). We shall not go into details here, only give the final conclusion that the described method is suitable to determine the process of evolution of the blown-out detritus and even to play the process back by carrying out the computation in the reverse order, starting from the end product. The computation serves the determination of principially possible compositions, independently of absolute time and space parameters. The reverse computation is suitable to establish the possible ways of development of the grain size distribution. The locality and time at which the individual stages determined by calculation are reached by the actually outblown mateiral depend on the variations of the transporting capacity of the wind.

For the purpose of further computations we have analyzed a desert sand from Libya. We have determined the principal stages of the evolution of the sand aand converted the grain size distribution results into weight percents. The results are summarized in the annexed table.

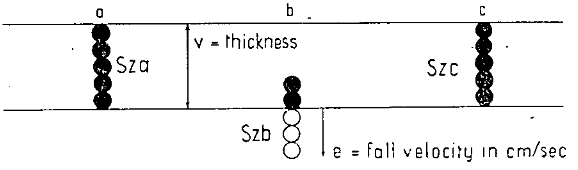


Fig. 24.

Fig. 25. represents the grain-size distribution data obtained by calculation by a set of cumulative curves. It is readily recognized that before the dust fraction is enriched there appears a graph much resembling that of a loessy fine sand. Hence, the peak characterizing the loessy fine sand must necessarily appear in the sorting of natural sands before the development of the dust peak. It is obvious that this material has to be homogeneous, even if it forms a series of considerable thickness; that is, its accumulation does not consist in the superposition of layers of significantly different grain size cistribution (that is, distance of transport). Loessy fine sand is formed out of suspended material which did not yet reach the state of the dust maximum, generally owing to the repeated gusts of a wind of generally identical transporting

Calculated changes of the total weight and grain size distribution of sand transported in suspension under internal sorting, expressed in weight percents.

Cycle	0,01—0,02	0,02—0,05	0,05—0,1	0,1—0,2	0,2—0,3	0,3—0,5	0,5—1,0	1,0—2,0	mm Ø	Total weight %
Original material	0,122	0,274	8,807	22,905	23,600	12,766	21,190	9,387	weight percent	100,000
1.	0,286	0,636	16,088	30,567	25,687	11,478	13,036	2,223		42,262
2.	0,562	1,231	24,547	34,073	23,353	8,620	6,700	0,446		21,383
3.	1,000	2,164	34,000	34,479	19,274	5,878	3,126	0,080		11,918
4.	1,642	3,514	43,472	32,207	14,683	3,144	1,350	—		7,196
5.	2,495	5,272	51,381	27,811	10,341	2,152	0,532	—		4,699
10.	10,388	20,660	61,089	6,873	1,000	0,739	—	—		1,084
15.	21,650	40,570	36,380	1,564	0,042	—	—	—		0,499
20.	30,900	54,440	14,200	0,060	—	—	—	—		0,336
25.	37,630	62,420	—	—	—	—	—	—		0,265

capacity within a given cycle of sedimentation. This wind may either be a long-range one of greater transporting capacity or a local wind of smaller capacity.

The case is different with loessy sand, or, speaking more exactly, with the two-peak loessy sand. It is clear in the figure that in the course of transport the originally two-peak sand turns into a one-peak one and that no second maximum crops up in the subsequent stages of sorting. This is also a general

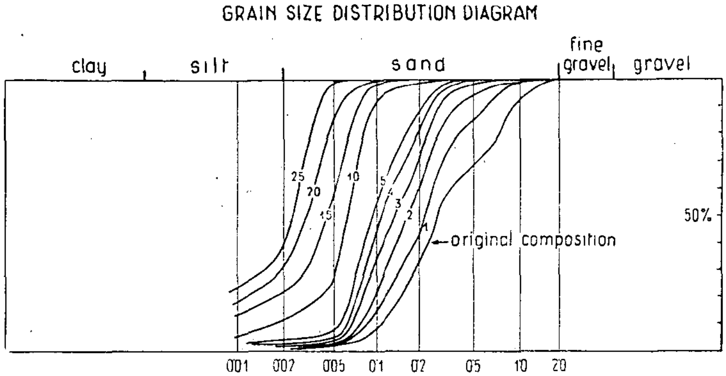


Fig. 25. Process an internal sorting of sand transported in suspension as revealed by the analysis of the eight grain size fractions from 0,01 to 2,0 mm of a sand sample from the Libyan Desert, collected by E. VADÁSZ.

1., 2. Sand stage
3., 4., 5. Stage of loessy sand
10. Stage of loessy fine sand
15., 20., 25. Stage of loess

law of the evolution of grain size distribution: the suspended material has no stage of evolution tending towards a two-peak state. Two peaks can be solely characteristic of outblown material. Sands of this kind cannot be formed except by the mixing of two materials of significantly different grain size, that is, of significantly different distance of transportation and sorting, out of at least two different sediments. In nature, this is realized by the mixture of local, rolled wind-blown sand and suspended dust of long-range transport. This sediment is of a heterogeneous nature. As a consequence, it is not permissible to speak of full sequences of evolution in cases like this, since the dust material is of foreign origin rather than a product of the sediment source of the sand. In this case the dust material of the loess attached to the deposit of transition is also of a more distant origin than the sand fraction. The same is valid for twopeak loess.

The two-peak loessy sand types are especially frequent as vertical transitions, interbeddings between wind-blown sand and loess. Concerning the formations of the horizontal transition we have not yet sufficient evidence, but what is available suggests that here one-peak loessy sand is the more frequent. The composition of this sediment does not exclude the possibility of a homogeneous formation, that is; the deposit is not necessarily heterogeneous, it is not necessary to postulate the mixing of local sand and faraway dust.

To clear the problem in this respect we can make use of another posibility: we must start from the numerical conditions and see whether the loessy sand types of known grain size distribution of the Hungarian Pleistocene could possibly have formed out of wind-blown sand. The problem encompasses an even wider field of facies studies and requires the processing of a huge amount of data. However, there is nothing impossible about its solution, at least in principle.

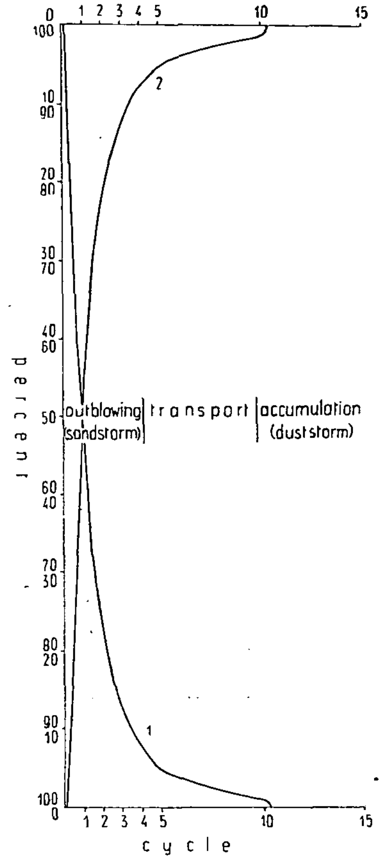


Fig. 26. 1. Amount of transported material in percents of total weight.
2. Amount of settling material in percents of total weight.

Finally, let us present as Fig. 26. for the sake of the quantitative characterization of the internal sorting process the curves of the abundance of the transported and deposited fractions, suitable to define the natural boundaries of the principal stages of sedimentation. The two curves refer to the case of a uniform transporting current and to an accumulation taking place in the tenth cycle of evolution. It is characteristic that the curves have one nearly horizontal section and two nearly vertical ones each. The first vertical section represents the loss of the coarser grains. the horizontal section the transport of the gradually refined grain assemblage, and finally, the second vertical section the deposition of the dust and fine sand. These sections correspond to the stages of blowout, transport and deposition, respectively. In the initial stage there is a sandstorm, in the final stage a duststorm.

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az MSZ 5601-59 sz. szabvány szerint
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